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**PHYSICAL AND CHEMICAL
CHARACTERISTICS OF
OILFIELD PRODUCTION
FACILITY WASTE SLUDGES
AND SOLIDS**



CANADIAN PETROLEUM ASSOCIATION

**PHYSICAL AND CHEMICAL
CHARACTERISTICS OF OILFIELD
PRODUCTION FACILITY
WASTE SLUDGES AND SOLIDS**

Prepared for:

**Canadian Petroleum Association
and
Environment Canada**

Prepared by:

David Bromley Engineering (1983) Ltd.

FEBRUARY, 1991

Funding for this research was provided by the Canadian Petroleum Association's Environmental Research Advisory Council (ERAC) and Environment Canada resources obtained from the Federal Panel for Energy Research and Development (PERD).

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ACKNOWLEDGEMENTS

David Bromley Engineering (1983) Ltd. (DBEL) wishes to acknowledge the assistance of the Steering Committee throughout this project. Members of the Steering Committee were as follows:

- Mr. B. Byers, Chairman, Gulf Canada Resources Ltd.
- Mr. R. P. Scroggins, Environment Canada
- Mr. R. K. Johnson, Shell Canada Limited
- Mr. A. Fernandes, Alberta Environment
- Mr. A. Cummins, Alberta Environment
- Mr. R. Creasy, Energy Resources Conservation Board
- Mr. S. Skarstol, Energy Resources Conservation Board
- Ms. S. Halla, Energy Resources Conservation Board
- Mr. M. J. Burley, Esso Resources Canada Ltd.
- Mr. M. Bradshaw, Petro-Canada Inc.

DBEL also acknowledges the assistance provided by the following companies in providing the sludge samples used in the project:

- Amoco Canada Petroleum Company Ltd.
- BP Resources Canada Limited
- Esso Resources Canada Ltd.
- Gulf Canada Resources Ltd.
- Husky Oil Ltd.
- Norcen Energy Resources Ltd.
- Petro-Canada Inc.
- Shell Canada Limited

In addition, DBEL acknowledges the services provided by Chemex Labs Alberta Inc., who carried out the laboratory analysis of the sludge samples.

Funding for this project was provided by the Environmental Research Advisory Council of the Canadian Petroleum Association and the Federal Panel for Energy Research and Development.

EXECUTIVE SUMMARY

This report presents the findings of a study undertaken to develop a data base of physical and chemical characteristics for the following six (6) different waste sludges and solids produced by upstream oil production operations:

1. Process Pond Sludge
2. Flare Knock-Out Drum Sludge
3. Flare Pit Sludge
4. Treater Bottom Sludge
5. Tank Bottom Sludge
6. Spill Material

The purpose of undertaking the study was to compile data to assist in the evaluation of treatment technology options for these waste materials, currently being carried out under another CPA/Environment Canada sponsored project.

The study involved assembling the data base using information obtained from a comprehensive field sampling and laboratory analytical program. The field sampling and laboratory analytical program involved obtaining three (3) samples of each sludge type from different production facilities, and having these samples analyzed for as many as thirty-seven (37) different physical and chemical parameters. A summary of the laboratory analytical program is presented in Table 1. An assessment of the quality of the data base was also prepared using the results obtained from the laboratory quality control program implemented for the project. In addition, a preliminary evaluation of the physical and chemical characteristics of the sludges and solids as they relate to the definition of a hazardous waste as defined in the Alberta Hazardous Waste Regulation was carried out. While not originally a part of the project scope of work this evaluation was undertaken because a number of the parameters analyzed can be used to evaluate the classification of the sludges relative to the Hazardous Waste Regulation.

TABLE 1 - LABORATORY ANALYTICAL PROGRAM

PARAMETERS ANALYZED	
1. Biochemical Oxygen Demand	19. Soluble Calcium
2. Total Organic Carbon	20. Soluble Magnesium
3. Total Phosphorus	21. Soluble Sodium
4. Total Kjeldahl Nitrogen	22. Soluble Potassium
5. % Solids	23. Soluble Chloride
6. % Water	24. Soluble Sulphate
7. Oil and Grease	25. Soluble Bicarbonate
8. Btu Content	26. Soluble Nitrate
9. Total Sulphur	27. Soluble Sulphide
10. Specific Gravity	28. Leachable Arsenic
11. pH	29. Leachable Barium
12. Electrical Conductivity	30. Leachable Barium
13. % Sand	31. Leachable Cadmium
14. % Silt	32. Leachable Chromium
15. % Clay	33. Leachable Lead
16. Free Liquids	34. Leachable Mercury
17. Flashpoint	35. Leachable Selenium
18. Flammability	36. Leachable Cyanide
	37. Leachable Nitrate/Nitrite

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The study concludes that in general, the quality of the data base is acceptable for the evaluation of treatment technology options. It was also concluded that the laboratory analytical procedures used to analyze selected parameters in the sludges and solids were generally acceptable. In addition, it was concluded that all six (6) sludges could potentially be classified as hazardous based on the Alberta Hazardous Waste Regulation. Finally, it was concluded that leachates generated from all six (6) sludges did not contain concentrations of metals, cyanides and nitrate/nitrite which exceed the limits of a TDGR 9.3 dangerous material.

This report recommends that in future, larger sample volumes should be collected to undertake the analysis performed in this study. In addition, it is recommended that the classification of the sludges as either hazardous or non-hazardous, should be based on a case-by-case, site specific sampling and analytical program. Finally, it is recommended that, due to the high oil content associated with these sludges, a more detailed organic analysis should be carried out to determine the concentrations of selected TDGR Class 9.2 materials in the sludges prior to assigning a hazardous or non-hazardous classification.

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1.0 INTRODUCTION

In October 1989, David Bromley Engineering (1983) Ltd. (DBEL) was retained by the Canadian Petroleum Association (CPA) and Environment Canada, to assemble a data base of physical and chemical characteristics of the following six (6) sludges and solids common to upstream oil production operations.

1. Process Pond Sludge
2. Flare Knock-Out Drum Sludge
3. Flare Pit Sludge
4. Treater Bottom Sludge
5. Tank Bottom Sludge
6. Spill Material

The purpose of undertaking this exercise was to compile data to supplement data obtained from another CPA/Environment Canada sponsored project, which was undertaken to evaluate treatment technology alternatives for sludges and contaminated soils (CH₂M Hill Engineering, 1989).

This report presents the results of the study and summarizes its findings. Section 2.0 outlines the methodology used to obtain the data, and compile the data base. Because all of the data was obtained from a field sampling and laboratory analytical program, detailed descriptions of the procedures used to collect and analyze the samples are presented in this section.

Particular emphasis is placed on outlining the quality control procedures used in the laboratory.

Section 3.0 of the report presents the results associated with the study. Results presented include a summary of the physical and chemical characteristics of each sludge; a summary of statistical parameters associated with the data collected; descriptions of the sampling procedures used to obtain the individual sludge samples; results of the laboratory quality control program; and a summary of the problems encountered during the laboratory analysis of the waste materials.

The results of the study are then discussed in Section 4.0. Subjects addressed in this discussion are as follows:

1. The quality of the data.
2. An assessment of the physical and chemical characteristics of the sludges as they relate to treatment technology selection and the Alberta Hazardous Waste Regulation.
3. The suitability of the sampling procedures used in this study.
4. The suitability of the laboratory procedures used in this study.

Based on the discussion of the above, conclusions and recommendations are developed within this section, and are then formally presented in Sections 5.0 and 6.0 respectively.

2.0 METHODOLOGY

The data base was assembled through a comprehensive field sampling and laboratory analytical program. However, prior to obtaining any information, it was necessary to first define the sludges being considered in the project. Because of the variations in configurations within oil production facilities, a standardized nomenclature for waste materials has not been developed. As such, it was necessary to develop definitions for the six (6) waste sludges and solids being considered in order to facilitate future treatment technology evaluations.

A list of definitions for the six (6) waste sludges and solids is presented below. For the most part, these definitions have been adapted from those contained in the CPA Petroleum Industry Waste Management Study Phase II report (Wotherspoon and Associates and DBEL, 1989). These definitions were used when discussing sample collection procedures with plant operating staff.

i) Process Pond Sludge

This sludge includes sludges contained in the bottom of various waste and wastewater storage, holding and evaporation ponds. Sludges from ecology pits are also included under this classification.

ii) Flare Knock-Out Drum Sludge

This sludge includes those liquids and sludges found in separation facilities upstream of flare stacks. They are typically found at batteries and fieldgates.

iii) Flare Pit Sludge

This sludge includes all sludges and solids which accumulate at the bottom of flare pits. They can be found at batteries, fieldgates and wellsites not tied into flowlines.

iv) Treater Bottom Sludge

This sludge includes all sludges and solids which accumulate at the bottom of oil, water and gas separators. Again, they can be found at batteries, fieldgates and individual wellsites not tied into flowlines.

v) Tank Bottom Sludge

This sludge includes all sludges and solids which accumulate at the bottom of oil storage tanks. Again, they can be found at batteries, fieldgates and individual well sites.

vi) Spill Material

This sludge includes all hydrocarbon or saltwater contaminated soil. It can be found at drilling and completion sites, batteries, fieldgates and individual wellsites.

It was also necessary to select the parameters to be included in the data base prior to collection of the data. Selection of these parameters was based on identifying those physical and chemical parameters which would be required to evaluate treatment technology options. Through discussions and meetings with the project steering committee, the members of which represent the CPA, Environment Canada, Alberta Environment and the ERCB, it was decided to include the following parameters in the data base. The rationale used for the selection of these parameters is identified below.

1. Parameter(s): Biochemical Oxygen Demand (BOD₅), Total Organic Carbon (TOC), Total Phosphorus (TP), Total Kjeldahl Nitrogen (TKN), Nitrate (NO₃⁻), Sulfide, Sulphate (SO₄²⁻)

 Rationale: Can be used to assess the potential for biological treatment and /or land application.
2. Parameter(s): % Solids, % Water, Particle Size Distribution (% Sand, Silt and Clay)

 Rationale: Can be used to assess the potential for various mechanical dewatering techniques.
3. Parameter: Oil and Grease

 Rationale: Can be used to assess both oil recovery and dewatering techniques. In addition, provides some indication of whether the

waste is hazardous based on TDGR Class 9.2 if it's concentration exceeds 100 mg/kg.

4. **Parameter:** British Thermal Unit (Btu) Content

Rationale: Can be used to assess the potential for incineration.

5. **Parameter(s):** Total Sulphur, Soluble Ions (Calcium, Magnesium, Sodium, Potassium, Chloride), Electroconductivity

Rationale: Can be used to assess the potential for land application.

6. **Parameter:** Specific Gravity

Rationale: Can be used to assess the potential for mechanical separation(eg/ flotation) and dewatering techniques.

7. **Parameter:** pH

Rationale: Can be used to assess land and biological treatment options. In addition, it provides some indication of whether or not the waste is hazardous or non-hazardous based on TDGR Class 8, Corrosive Materials. While the TDGR Class 8 classification is based on a specified corrosivity test, Alberta Environment consider wastes having pH's less than 2.0 or greater than 12.0, to be hazardous wastes (Fernandes, 1989).

8. Parameter: Flashpoint
- Rationale: Can be used to classify the waste as hazardous or non-hazardous based on TDGR Class 3, Flammable Liquid, if the measured flashpoint is less than 61°C.
-
9. Parameter: Flammability
- Rationale: Can be used to classify the waste as hazardous or non-hazardous based on TDGR Class 4, Flammable Solids, if the waste will combust spontaneously.
-
11. Parameter: Free Liquid
- Rationale: Used to determine whether or not the waste is a liquid or a solid and hence, can be used in evaluating the use of landfilling as a disposal option.
-
12. Parameter: Leachable Metals (Arsenic, Barium, Boron, Cadmium, Chromium, Lead, Mercury, Selenium), Leachable Cyanide, Leachable Nitrate/Nitrite
- Rationale: Can be used to determine whether or not the waste is hazardous based on TDGR Class 9.3, Leachable Wastes. It should be noted that the analyses conducted on the leachate did not encompass all of the parameters required to fully assess the

TDGR 9.3 classification. Parameters which were not tested include PCB's and a number of other organic compounds (predominately pesticides). These parameters were not tested as it was felt that their occurrence in the waste sludge would be on a site specific basis.

It should be noted that a number of the parameters (ie/ flashpoint, flammability, leachable metals, leachable cyanides, leachable nitrate/nitrite) were selected in order to provide an indication of whether or not the wastes are hazardous based on the Alberta Hazardous Waste Regulation. While not specifically required to evaluate treatment technology options, these parameters are useful since the regulations impose certain requirements which may impact on the way in which the waste is treated. For example, liquid hazardous wastes containing the following components at concentrations exceeding the specified limits, may not be landfilled in Alberta:

- i) Free Cyanides > 1000 mg/kg
- ii) Arsenic $\geq$ 500 mg/kg
- iii) Cadmium $\geq$ 100 mg/kg
- iv) Chromium (Cr^{+6}) $\geq$ 500 mg/kg
- v) Lead $\geq$ 500 mg/kg
- vi) Mercury $\geq$ 100 mg/kg
- vii) Nickel $\geq$ 134 mg/kg
- viii) Selenium $\geq$ 100 mg/kg

- ix) Thallium $\geq$ 130 mg/kg

Therefore should a particular sludge be classified as hazardous liquid waste, and contain one or more of the above listed components at concentrations exceeding those specified, there may be some incentive to consider dewatering as a treatment option in order to permit landfill disposal.

2.1 Field Sampling Program

A total of eighteen (18) sludge samples were obtained from ten (10) different oilfield production facilities throughout Alberta and Saskatchewan. Three (3) samples of each sludge were taken - one (1) sample from three (3) different facilities.

Samples were collected by both DBEL and the operations staff at the various plants. Standardized sampling techniques were used as much as possible, recognizing that there are considerable variations in the locations of the sludges within the different facilities. In general, the following procedures were followed:

1. Onsite meetings were held with plant staff prior to sampling. Where samples were obtained by the operations staff, telephone conversations were used to ensure that plant personnel understood both the type of sludge required, and the sampling procedures to be followed.

2. Samples were collected in glass bottles. This was based on the recommendation of the analytical laboratory (Chemex Labs Alberta Inc.) retained for the project. Where samples were collected by operations staff, glass sample bottles were sent to the plant by DBEL. In most cases they were used.
3. A minimum sample volume of 500 mL was collected. This again was based on the recommendation of Chemex.
4. Where possible, composite samples were made by combining samples taken over a large area and from different depths.
5. Pond samples were collected using a vacuum pump apparatus. This proved to be an effective method for obtaining sludge samples in ponds up to 6.0 m in depth and was very conducive to making composite samples.
6. In shallow sumps or pits, grab samples were taken using a plastic bottle attached to a pole. A number of samples were taken and combined to form a composite sample.
7. Samples were stored in an ice-filled cooler after collection to retain their characteristics.
8. Samples were usually sent to the laboratory within 1 day of collection.

9. All equipment was thoroughly cleaned prior to reuse to avoid cross contamination.

2.2 Laboratory Analytical Program

Sample preparation at the laboratory was carried out in accordance with CPA procedures (Monenco Consultants Ltd., 1987). Upon arrival at the laboratory, samples were thoroughly shaken and then allowed to decant for 24 hours. Supernatant was then removed and analysis of the samples was performed. All samples were analyzed for all of the parameters listed in Table 1. The only exception to this was that leachate tests were not carried out on samples which could be classified as hazardous based on flashpoint, flammability or corrosivity (pH).

Analytical protocol was carried out in accordance with the procedures listed in Table 2. These procedures were reviewed by the Steering Committee prior to undertaking the analysis.

2.3 Laboratory Quality Control Procedures

A formalized quality control program was used by Chemex for this project. This program involved carrying out the following 3 checks on the analytical techniques and equipment used:

TABLE 1 - LABORATORY ANALYTICAL PROGRAM

PARAMETERS ANALYZED	
1. Biochemical Oxygen Demand	19. Soluble Calcium
2. Total Organic Carbon	20. Soluble Magnesium
3. Total Phosphorus	21. Soluble Sodium
4. Total Kjeldahl Nitrogen	22. Soluble Potassium
5. % Solids	23. Soluble Chloride
6. % Water	24. Soluble Sulphate
7. Oil and Grease	25. Soluble Bicarbonate
8. Btu Content	26. Soluble Nitrate
9. Total Sulphur	27. Soluble Sulphide
10. Specific Gravity	28. Leachable Arsenic
11. pH	29. Leachable Barium
12. Electrical Conductivity	30. Leachable Barion
13. % Sand	31. Leachable Cadmium
14. % Silt	32. Leachable Chromium
15. % Clay	33. Leachable Lead
16. Free Liquids	34. Leachable Mercury
17. Flashpoint	35. Leachable Selenium
18. Flammability	36. Leachable Cyanide
	37. Leachable Nitrate/Nitrite

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TABLE 2 - LABORATORY ANALYTICAL PROTOCOL

PARAMETER	METHOD
BOD Biochemical Oxygen Demand	Sudge/sediment is diluted in distilled water and BOD conducted according to NAQUADAT0802. Seed will be added and five day BOD measured with the Winkler procedure. BOD will be reported as ug/g wet sudge. Detection Limit = 1 ug/g
COD Chemical Oxygen Demand	Sudge/sediment is diluted in distilled water and COD conducted according to NAQUADAT0804 - a semi-automated colorimetric procedure utilizing $H_2SO_4-Ag_2SO_4$ and $K_2Cr_2O_7$ heated to 150 °C for 2 hours. Colorimetric determinations made at 600nm. Detection Limit = 5 ug/g
TOC Total Organic Carbon	Total organic carbon will be determined using the Walkley-Black technique. A reflux method using H_2SO_4 and reduction of potassium dichromate. Detection Limit = 0.1 weight %
TP Total Phosphorous	Semi-automated - Perchloric digestion. NAQUADAT01301. Sample is ground to 120 mesh, digested with sulphuric acid, potassium persulfate. Phosphorous is determined using ICP-AES at 178 nm. Detection limit = 1 ug/g
TN Total Kjeldahl Nitrogen	Total Kjeldahl Nitrogen - sample is digested in conc H_2SO_4 potassium persulfate and perchloric acid. The converted ammonia is analysed on an autoanalyser system, utilizing the Berthelot reaction and measured at 605nm. Detection Limit = 1 ug/g
NO_3^- Nitrate	Sudge/sediment is diluted in distilled water and extracted on a mechanical shaker for 4 hours. The solution is filtered through 0.45 micro cellulose acetate paper and the soluble nitrate is measured by Ion Chromatography. Detection Limit = 0.005 ppm
Sulfide	The original sudge/sediment is diluted in distilled water and this solution is analysed using Iodometric method (titrimetric with Standard Sodium thiosulfate). Detection Limit = 0.01 ppm
SO_4 Sulphate	Prepared as per nitrate, the filtered solution is analysed for sulphate utilizing ion chromatography and conductivity detection. Detection Limit = 1 ppm
% Solid/ % Water	If sample is high in oil, as determined by Dens-Check procedure, the sudge is placed in a porous thimble and refluxed in toluene until the filtrate is clear. Separate percent determinations are made on oil, water, solids portions. Detection Limit = 1 ppm
O & G Oil and Grease	Oil and grease is determined utilizing an infrared technique NAQUADATCODE 08534. The sudge is extracted with hexane and the extract measured on a infrared spectrophotometer at $2930cm^{-1}$. Detection Limit = 1 ppm
TOTAL S Total Sulphur	Performed by Leco Induction furnace. The sample is heated in an induction furnace at 2000 °C. The sulfur dioxide evolved from the oxidation of all sulphur forms is automatically titrated in an iodine-potassium iodide solution. Detection Limit = 0.01% by weight
S.G. Specific Gravity	Carried out on the deoiled sudge slurry using a calibrated pycnometer. Detection Limit = 0.01
pH	The pH will be confirmed on the original sample or a saturated extract using a pH meter equipped with a pH combination electrode.

TABLE 2 - LABORATORY ANALYTICAL PROTOCOL CONTINUED

PARAMETER	METHOD
ROUTINE CATIONS/ANIONS Detection Limits Ca - 0.1 ppm Mg - 0.1 ppm Na - 0.1 ppm K - 0.1 ppm Cl - 0.1 ppm HCO ₃ - 0.5 ppm	<u>On a 2:1 extract</u> Cations to be determined include Ca, Mg, Na, K. Calcium and magnesium will be determined by atomic absorption using nitrous oxide/acetylene flame. Sodium and potassium will be measured by flame emission spectroscopy. Alkalinity will be determined by potentiometric titration with H ₂ SO ₄ . Anions include SO ₄ , Cl and HCO ₃ . The sulphate procedure has been described earlier, Cl will be analyzed by ion chromatography and conductivity detection.
PARTICLE SIZE DISTRIBUTION	Particle size will be conducted using the Bouyoucos hydrometer technique and 50 gms of air dried sediment.
ELC. Electrical Conductivity	Conductivity will be measured on extract of slurry or saturated paste utilizing a conductivity meter.
FLASHPOINT/FLAMMABILITY	Flammability will be measured the Pensky-Martens Closed Cup flash point apparatus. The apparatus will be modified for unstirred solids by performing the same test with the stirrer disconnected.
LEACHATE	The leachate test will be conducted according to the procedure described in "The Canadian General Standards Board Class 9, Macerated Solventless COSB Leachate Extraction Procedure". Test methods used will be in accordance with US EPA SW-846 "Test Methods for Evaluating Solid Waste".
FREE LIQUID	Free liquid will be determined utilizing the US EPA SW-846 paint filtrant technique.
B.T.U.	Will be determined using a calorimeter to measure heating value (BTU).
CYANIDE	Chloramine-T, pyridine barbituric acid colourimetry on an auto-analyser. Sample is acidified, distilled and buffered, then reacted with chloramine-T and a pyridine-barbituric acid reagent. The colour is measured spectrophotometrically at 580nm and compared with standard KCN solutions. Detection Limit - 0.001 ppm
ARSENIC and SELENIUM	Semi-automated flameless atomic absorption. Manual digestion of samples with sulfuric and nitric acids, followed by NaBH ₄ reduction and measurement at 193nm and 196nm respectively. Detection Limit - 0.0002 ppm for both
BARIUM, BORON, CADMIUM, CHROMIUM and LEAD	By inductively coupled argon plasma emission spectroscopy. The sample is aspirated: emission is measured at 455.4nm, 249.7nm, 228.8nm, 267.7nm and 220.3nm respectively and compared with that of standard solutions. Detection Limits: Ba - 0.01; B - 0.01 ppm; Cd - 0.001 ppm; Cr - 0.001 ppm; and Pb - 0.01 ppm.
MERCURY	Flameless atomic absorption on an autoanalyser. Sample is mixed with KMnO ₄ and conc. H ₂ SO ₄ , then digested at 105 °C. This solution is then mixed with hydroxylamine sulphate and NaCl, the SnSO ₂ . The mixture is sparged with air, the liquid removed by a gas separator and the air flow, containing Hg vapour, is then passed through an absorption cell. Absorbance is measured spectrophotometrically at 253.7nm and compared to standard mercury solutions. Detection Limit - 0.01 ppb

1. Standard check solutions having known concentrations of specific parameters were prepared by Chemex's quality control department, and analyzed by the technician(s) performing the sludge analysis. The results were then compared to theoretical concentrations and expressed in terms of percent recovery. This component of the quality control program was used to confirm that the technician(s) were performing the analysis correctly, and that the analytical equipment was functioning properly.
2. Sludge samples were "spiked" with known amounts of specified compounds and were then analyzed. The results were then compared to the theoretical "spiked" concentrations, and expressed in terms of percent recovery. Again, the purpose of this check was to confirm that the technician(s) were performing the analysis correctly and that the analytical instruments were functioning properly. In addition, this check can also be used to identify interferences in the analytical technique.
3. Duplicate analyses of the samples were performed to assess the reproducibility of the analytical techniques. The differences between the results were statistically compared with Chemex's historical data to determine if the reproducibility of the results was acceptable.

2.4 Data Compilation

Upon completion of the analytical work, results were input to Lotus 1-2-3 spreadsheets. The following statistical parameters were then calculated for each parameter analyzed:

- Mean;
- Minimum Value;
- Maximum Value; and
- Standard Deviation.

It is recognized that the mean and standard deviation calculations were based on a small sample population (3 samples) and hence, their statistical significance is likely very questionable. However, it was decided to include these parameters in the report as they provide an indication of the variability associated with the results.

3.0 RESULTS

The results of this study include the following:

1. A summary of the physical and chemical characteristics for each of the 6 sludge types.
2. A report outlining the procedures followed in obtaining each sample.
3. A set of quality control reports that were prepared by the laboratory that analyzed the sludge types.
4. An account of the problems encountered by the laboratory during the analytical process.

3.1 Physical and Chemical Characteristics

Data obtained from the sampling/analytical program is presented in Appendix A for each sludge. Two sheets summarizing the physical and chemical properties have been provided for each sludge. These are as follows:

1. A summary of the physical and chemical properties based on the sampling/analytical program.
2. A summary of the statistical parameters associated with the data presented in
 1. Values for the mean, minimum value, maximum value and standard deviation value are presented.

3.2 Sampling Reports

Appendix B presents sampling reports identifying the procedures used for obtaining each sludge sample.

3.3 Quality Control

Detailed results of the quality control program are presented in Appendix C. Summaries of the quality control program results are presented in Tables 3, 4 and 5. Table 3 presents a summary of the percent recoveries associated with the analysis of the standard check solutions. As shown in this table, measured concentrations ranged from 85.2% to 125.0 % of the theoretical concentrations of the parameters in solution.

TABLE 3 - QUALITY CONTROL PROGRAM RESULTS - STANDARD CHECK SOLUTION

PARAMETER	STANDARD CHECK SOLUTION (% RECOVERY)					
	SAMPLE #1	SAMPLE #2	SAMPLE #3	SAMPLE #4	SAMPLE #5	SAMPLE #6
Total Organic Carbon	105	98	102			
Total Phosphorous	93.8	85.2				
Total Kjeldahl Nitrogen	98.2	110	105.3			
Soluble Ions (Total Sample)						
Calcium	100	105	90			
Magnesium	110	97	97.5			
Sodium	107	106	108			
Potassium	103	102	111			
Chloride	95	96.2	98.7			
Sulphate	98.3	103	98.3			
Nitrate as N	104					
Sulfide	100	94.2				
Leachate Analysis						
Arsenic	100	112.5	125	112.5		
Barium	97.1	96.6	93.6			
Boron	96.1	96.7	88.2			
Cadmium	100	99.3	98.1			
Chromium	97.7	95.3	92.3			
Lead	102.5	104.3	97.2			
Mercury	109	97	110			
Selenium	113	77.7	111	112.5		
Cyanide	107	102.3	97.6	100	98	100

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TABLE 4 - QUALITY CONTROL PROGRAM RESULTS - SPIKED SAMPLES

PARAMETER	SPIKED SAMPLE (% RECOVERY)					
	SAMPLE #1	SAMPLE #2	SAMPLE #3	SAMPLE #4	SAMPLE #5	SAMPLE #6
Total Kjeldahl Nitrogen	108	100	98			
Soluble Ions (Total Sample)						
Chloride	100	101	100.7			
Sulphate	100.7	100	100			
Nitrate as N	96.5					
Leachate Analysis						
Arsenic	100	103.9	100	94.2	98.2	101.3
Barium	100	98.9	94.9			
Boron	103.5	100	118.2			
Cadmium	97.2	115	96.3			
Chromium	97.7	90.9	102.5			
Lead	91.6	112.5	100.5			
Mercury	87.6	105	101	98.2		
Selenium	102	97.7	105	90	98.1	104
Cyanide	100	100	96	87	96.4	100

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TABLE 5 - QUALITY CONTROL PROGRAM - DUPLICATE SAMPLE ANALYSIS

PARAMETER	DUPLICATE ANALYSIS ACCEPTABILITY						
	SAMPLE 1	SAMPLE 2	SAMPLE 3	SAMPLE 4	SAMPLE 5	SAMPLE 6	SAMPLE 7
Total Kjeldahl Nitrogen	YES	YES	YES	YES			
Total Sulphur	N.A.	N.A.	N.A.	N.A.			
pH	YES	YES					
Electrical Conductance	YES	YES	YES				
Soluble Ions							
Calcium	N.A.	N.A.	N.A.	N.A.			
Magnesium	N.A.	N.A.	N.A.	N.A.			
Sodium	N.A.	N.A.	N.A.	N.A.			
Potassium	N.A.	N.A.	N.A.	N.A.			
Chloride	YES	YES	YES	YES			
Sulphate	YES	YES	YES				
Bicarbonate	N.A.	N.A.	N.A.				
Nitrate as N	N.A.						
Sulfide	N.A.	N.A.					
Leachate Analysis							
Arsenic	YES	YES	YES	YES	YES	YES	YES
Barium	YES	YES	YES				
Boron	YES	YES	YES				
Cadmium	YES	YES	YES	YES			
Chromium	YES	YES	YES				
Lead	YES	YES	YES	YES			
Mercury	YES	YES	YES	YES	YES		
Selenium	YES	YES	YES	YES	YES	YES	YES
Cyanide	YES	YES	YES	YES	YES	YES	

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"N.A." Indicates that Chemex Labs Alberta Inc. did not have sufficient in-house historical data to assess.

Table 4 summarizes the percent recoveries associated with the analysis of the spiked samples. As shown, measured concentrations of the spiked parameters ranged from 84.0% to 118.2% of the actual concentration of the parameter added.

Table 5 presents a synopsis of the results from the duplicate analysis checks. This table indicates that, where Chemex had a sufficient historical data base to draw statistical conclusions, all duplicate analyses performed were within the acceptable confidence limits of 95%. However, it should be noted that Chemex had sufficient historical data from which to draw conclusions for only 14 of the 39 parameters considered in this project. It should also be noted that the results for the spiked and duplicate samples (Tables 4 and 5) include results from other projects being undertaken at the same time. For example, if Chemex were analyzing soluble ions for another project at the same time as the analyses for this project were being carried out, then the spiked/duplicate analyses could have been undertaken on the sample(s) from the other project.

A review of Appendix C and Tables 3, 4 and 5 indicates that the quality control program did not encompass the analysis of the following parameters:

- | | |
|------------------|------------------------------|
| - BOD | - Particle Size Distribution |
| - Btu Content | - Flashpoint/Flammability |
| - Oil and Grease | - Specific Gravity |

- % Solids and Water - Free Liquids

The reasons for not implementing the quality control program for the analysis of these parameters are as follows:

1. It is difficult to prepare standard check solutions for these parameters.
2. It is difficult to prepare spiked solutions with these parameters.
3. Chemex did not have a large enough in-house historical data base to support the statistical analysis associated with the duplicate analysis check. Duplicate analysis could have been carried out for these parameters, but an evaluation of their statistical acceptability was not possible.

3.4 Laboratory Problems

The following problems were encountered by Chemex during the analysis of the sludges:

1. Some of the samples were in three distinct phases (oil, water and solids) and others had oil adhered to the sample container. Even after mixing, it was difficult to obtain a homogenous sub-sample which is necessary for some chemical analysis.
2. Many of the samples were high in sulfide content and therefore the Iodometric Titration procedure was used to determine sulfide concentration rather than the Ion

Chromatography method originally proposed.

3. Problems were encountered in analyzing one of the tank bottom sludges for water content. The cause of this problem was that the sample was water soluble and formed an emulsion with the toluene used in the Dean-Stark extraction procedure.
4. Problems were also encountered in performing the oil and grease analysis on one of the tank bottom sludge samples as the sample was soluble in both freon and methylene chloride extractions.
5. For all three flare knock-out and one of the treater bottom sludge samples, a 500 mL sample was insufficient in size to complete the analysis for particle size distribution (ie/ % sand, silt and clay). This was a result of the samples having low solids concentrations ($< 8\%$). As such, it was not physically possible to carry out the hydrometer analysis.

4.0 DISCUSSION

Within this section, the results presented in Section 3.0 are discussed. Items discussed are as follows:

1. The general physical and chemical characteristics of each sludge.
2. The quality of the data.
3. The suitability of the sampling procedures used in the study.
4. The suitability of the laboratory procedures used in the study.

4.1 General Physical and Chemical Characteristics

i) Process Pond Sludge

Based on the results of the free liquids analysis (see Table 1 in Appendix A), this sludge typically exists in a solid form. Oil, water and solids contents were relatively variable with concentrations of 11300 - 141000 ppm, 25.3 - 55.5% and 26.6 - 73.3% measured in the samples respectively. Based on the particle size distribution analysis, the percentage of solids having diameters less than 0.002 mm (clay size) is between 12 and 22 %; the percentage of solids having diameters from 0.002 to 0.07 mm (silt size) is between 34 and 59 %; and the percentage of solids having diameters from 0.07 to 2.0 mm (sand size) is between 12 and 59%.

The organic component of the sludge is somewhat variable, as TOC's ranged from 2.8 to

12.6% by weight. The sludge appears to be relatively biodegradable as BOD's ranged from 10950 to 20700 mg/L. Significant nutrient concentrations also appear to be present as TKN and TP concentrations ranged from 396 to 1500 ppm, and 377 to 1170 ppm, respectively. Btu contents were highly variable (297 to 4532 Btu/lb).

The sludge samples contained between 0.04 and 1.18 % of total sulphur by weight. Specific gravities were always greater than 1.0, with values from 1.14 to 1.77 measured. The sludge sample pH was consistently basic, as values of 9.8 to 10.6 were measured. Electrical conductivity was highly variable as values from 1280 to 48400 umhos/cm were determined. Sodium and chloride ions were generally the predominate ions present.

None of the sludge samples were found to be flammable based on TDGR test procedures. Leachates generated from the sludge samples did not contain metals, cyanide or nitrate/nitrite concentrations which exceed the limits set for TDGR Class 9.3 dangerous goods.

ii) Flare Knock-Out Sludge

Based on the results of the free liquids analysis (see Table 2 in Appendix A), this sludge typically exists in a liquid form. Oil, water and solids contents were relatively variable with concentrations of 5812 - 520000 ppm, 40.0 - 87.1 % and 1.0 - 7.9 % measured in the samples respectively. Because of the low solids concentrations, particle size distribution analysis was not undertaken.

The organic component of the sludge is highly variable, as TOC's ranged from 1.4 to 53.9% by weight. The organic component of the sludge does not appear to be highly biodegradable as BOD's ranged from only 1080 to 4820 mg/L. Consistent nitrogen concentrations appear to be present as TKN concentrations ranged from 465 to 764 ppm, but phosphorus concentrations are highly variable (0.1 - 190 ppm TP). Btu contents were also highly variable (400 to 19127 Btu/lb).

The sludge samples contained between 0.05 and 0.52 % of total sulphur by weight. Specific gravities ranged from 0.80 to 1.1. Sludge pH ranged from relatively acidic (pH 4.4) to neutral (pH 7.2). Electrical conductivity was highly variable as two samples had low conductivity (40 and 140 umhos/cm), while the conductivity of the third sample was relatively high (135000 umhos/cm). Sodium, potassium and chloride ions were the predominate ions in the sample having high conductivity.

One of the sludge samples was found to be flammable based on TDGR test procedures. Leachates generated from the sludge samples did not contain metals, cyanide or nitrate/nitrite concentrations which exceed the limits set for TDGR Class 9.3 dangerous goods.

iii) Flare Pit Sludge

Based on the results of the free liquids analysis (see Table 3 in Appendix A), this sludge typically exists in a solid form. Oil, water and solids contents were relatively variable with

concentrations of 4170 - 452000 ppm, 11.5 - 25.3 % and 38.3 - 71.2 % measured in the samples respectively. Based on the particle size distribution analysis, the percentage of solids having diameters less than 0.002 mm (clay size) is approximately 15 %; the percentage of solids having diameters from 0.002 to 0.07 mm (silt size) is between 5 and 32 %; and the percentage of solids having diameters from 0.07 to 2.0 mm (sand size) is between 54 and 81%.

The organic component of the sludge is somewhat variable, as TOC's ranged from 1.67 to 32.4 % by weight. The sludge does not appear to be overly biodegradable as BOD's ranged from 480 to 2715 mg/L. Nitrogen concentrations were quite variable (7.85 - 1860 ppm TKN) while phosphorus concentrations appear to be relatively consistent (350 - 363 ppm TP). Btu contents were highly variable (94 to 8219 Btu/lb).

The sludge samples contained between 0.54 and 3.4 % of total sulphur by weight. Specific gravities were always greater than 1.0, with values from 1.1 to 1.6 measured. Sludge pH ranged from acidic (pH 5.6) to slightly basic (pH 7.68). Electrical conductivity was highly variable as values from 3920 to 20200 umhos/cm were determined. Sodium, calcium, sulphate and chloride ions were generally the predominate ions present.

None of the sludge samples were found to be flammable based on TDGR test procedures. Again leachates generated from the sludge samples did not contain metals, cyanide or nitrate/nitrite concentrations which exceed the limits set for TDGR Class 9.3 dangerous goods.

iv) Treater Bottom Sludge

Based on the results of the free liquids analysis (see Table 4 in Appendix A), this sludge typically exists in a solid form. Oil, water and solids contents were relatively variable with concentrations of 21700 - 554000 ppm, 23.5 - 58.6 % and 8.14 - 61.8 % measured in the samples respectively. Based on the particle size distribution analysis, the percentage of solids having diameters less than 0.002 mm (clay size) is approximately 7 %; the percentage of solids having diameters from 0.002 to 0.07 mm (silt size) is between 23 and 58 %; and the percentage of solids having diameters from 0.07 to 2.0 mm (sand size) is between 17 and 70%.

The organic component of the sludge is relatively high, as TOC's ranged from 21 to 66.8 % by weight. The sludge does not appear to be highly biodegradable as BOD's ranged from 825 to 3360 mg/L. Nitrogen concentrations were relatively consistent (1320 - 3000 ppm TKN) while phosphorus concentrations were somewhat variable (6.8 - 336 ppm TP). Btu contents were relatively consistent (2011 to 7287 Btu/lb).

The sludge samples contained between 0.5 and 5.79 % of total sulphur by weight. Specific gravities were always greater than 1.0, with values from 1.01 to 1.56 measured. Sludge pH ranged from neutral (pH 7.05) to slightly basic (pH 8.27). Electrical conductivity was relatively consistent as values from 12700 to 26400 umhos/cm were determined. Sodium and chloride ions were generally the predominate ions present.

One of the sludge samples were found to be flammable based on TDGR test procedures. Again leachates generated from the sludge samples did not contain metals, cyanide or nitrate/nitrite concentrations which exceed the limits set for TDGR Class 9.3 dangerous goods.

v) Tank Bottom Sludge

Based on the results of the free liquids analysis (see Table 5 in Appendix A), this sludge can exist in both solid and liquid forms. Oil, water and solids contents were somewhat variable with concentrations of 3.6 - 10.5 %, 9.85 - 40.4 % and 0.7 - 80.5 % measured in the samples respectively. Based on the particle size distribution analysis, the percentage of solids having diameters less than 0.002 mm (clay size) is approximately 7 %; the percentage of solids having diameters from 0.002 to 0.07 mm (silt size) is between 15 and 85 %; and the percentage of particles having diameters from 0.07 to 2.0 mm (sand size) is between 7 and 78%.

The organic component of the sludge is relatively consistent, as TOC's ranged from 5.9 to 9.5 % by weight. The biodegradable fraction of the sludge is somewhat variable, as BOD's ranged from 19.5 to 2940 mg/L. Both nitrogen and phosphorus concentrations also appear to be somewhat variable (235 - 1470 ppm TKN and 3 - 226 ppm TP). Btu contents were also variable (886 to 3756 Btu/lb).

The sludge samples contained between 0.62 and 1.66 % of total sulphur by weight. Specific gravities ranged from 0.99 to 1.34. Sludge pH ranged from neutral (pH 6.89) to very basic (pH 11.3). Electrical conductivity was highly variable as values from 2420 to 28000 umhos/cm were determined. Sodium, bicarbonate, sulfide and chloride ions were generally the predominate ions present.

One of the sludge samples were found to be flammable based on TDGR test procedures. Again leachates generated from the sludge samples did not contain metals, cyanide or nitrate/nitrite concentrations which exceed the limits set for TDGR Class 9.3 dangerous goods.

vi) Spill Material

Based on the results of the free liquids analysis (see Table 6 in Appendix A), this sludge typically exists in the solid form. Oil, water and solids contents were relatively consistent with concentrations of 1.0 - 13.5 %, 0.6 - 8.0 % and 85.9 - 98.4 % measured in the samples respectively. Based on the particle size distribution analysis, the percentage of solids having diameters less than 0.002 mm (clay size) is between 11 and 27 %; the percentage of solids having diameters from 0.002 to 0.07 mm (silt size) is between 28 and 34 %; and the percentage of particles having diameters from 0.07 to 2.0 mm (sand size) is between 41 and 61%.

The organic component of the sludge is somewhat variable, as TOC's ranged from 3.8 to 14.0% by weight. The sludge does not appear to be overly biodegradable as BOD's ranged from 741 to 1557 mg/L. Nitrogen and phosphorus concentrations were relatively consistent (956 - 2000 ppm TKN and 97.6 - 185 ppm TP). Btu contents were also quite consistent (1300 to 1404 Btu/lb).

The sludge samples contained between 0.19 and 0.38 % of total sulphur by weight. Specific gravities ranged from 1.04 to 1.14. Sludge pH appears to be relatively neutral (pH 7.24 to pH 7.3). Electrical conductivity was highly variable as values from 7940 to 27400 umhos/cm were determined. Sodium, sulphate and chloride ions were generally the predominate ions present.

One of the sludge samples were found to be flammable based on TDGR test procedures. Again leachates generated from the sludge samples did not contain metals, cyanide or nitrate/nitrite concentrations which exceed the limits set for TDGR Class 9.3 dangerous goods.

4.2 Data Quality Assessment

The quality of the data obtained from the sampling and analytical program can be assessed through a review of the quality control program results, as presented in Tables 3, 4 and 5.

As previously discussed, Table 3 presents a summary of the standard check solution analyses. Results presented on this table show that the laboratory technicians measured concentrations ranging from 85.2% to 125.0% of the theoretical concentrations in standard check solutions. Whether or not this is acceptable is very subjective, however given that feasible treatment technologies must function over a relatively wide range of influent conditions, this range of variability is likely acceptable.

Table 4 presents a synopsis of the results of the spiked sample analysis. As shown on this table, measured concentrations of spiked parameters ranged from 87.0% to 118.2% of the actual concentration of the spiked parameters. Since "spiking" is used to confirm the suitability of the analytical procedures and the absence of interferences, these results suggest that the analytical procedures were generally accurate within 15-20%. Again, while somewhat subjective, this range of variability would appear to be acceptable for an assessment of treatment technologies.

Table 5 presents the results of the duplicate analysis. As shown on this table, all of the duplicates performed met Chemex's in-house standards for reproducibility, and hence, it can

be concluded that the data is acceptable for these parameters. However, it should be realized that duplicate analyses were not performed for the following parameters:

- BOD₅
- TOC
- TP
- % Solids and Water
- Oil & Grease
- Particle Size Distribution
- S.G.
- Flashpoint/Flammability
- Free Liquids

Whether or not it can be concluded that the results for the above parameters are reliable is again very subjective. Chemex noted that obtaining a homogenous mixture of some of the oily sludges was difficult due to the immiscible nature of the oil. However, all of the parameters tested in duplicate samples proved to be within acceptable concentration limits. As such, it is felt that the data is acceptable from a reproducibility perspective.

Because all three quality control checks (standard check solutions, spiked samples and duplicate samples) appeared to yield acceptable results, it is concluded that the data is acceptable for an assessment of treatment technologies for the waste sludges.

4.3 Sampling Procedure Suitability

Based on our discussions with the Steering Committee, the sampling procedures used in the project appeared to be acceptable. Problems related to insufficient sample volumes for the analysis of particle size distribution were encountered for sludges having low solids concentrations. In addition, in retrospect, Chemex would have preferred to have larger sample volumes to facilitate duplicate analysis, and experimentation with alternate analytical techniques. As such, they recommend collecting a minimum of 2.0 L of sample for the analysis of the parameters carried out in this study.

4.4 Laboratory Procedure Suitability

Given the favourable results of the standard solution and spiked sample checks, it appears that the laboratory procedures used to analyze the following parameters were acceptable:

- | | | | |
|-------------------|-------------------|-----------|------|
| • TOC | • TP | • TKN | • Ca |
| • Mg | • Na | • K | • Cl |
| • SO ₄ | • NO ₃ | • Sulfide | • CN |
| • As | • Si | • HG | • Ba |
| • B | • Cd | • Cr | • Pb |

Since checks were not performed on the remaining parameters, it is difficult to conclude that the techniques used to analyze these parameters were correct. Since problems were encountered in determining the oil and water content for one tank bottom sludge, it is evident that the methods employed were not acceptable for this sludge. Whether or not a

technique should be developed is debatable, since the knowledge of these parameters is only required for the preliminary evaluation of mechanical dewatering technologies. Since these technologies would have to be pilot plant-tested prior to implementing a full-scale dewatering system, the determination of these parameters may not be required.

It is felt that the procedures used for those parameters not checked within the Quality Control Program (BOD, % water, % solids, electrical conductivity, oil and grease, particle size distribution, flashpoint, flammability, Btu content, specific gravity, and free liquid) are relatively well-proven procedures, and hence were acceptable for this project. With the exception of the analysis for oil and water content of one of the tank bottom sludges, no applications were identified where the procedures could not be used. This opinion was supported by Chemex.

4.5 Hazardous and Non-Hazardous Considerations

The chemical analytical results for each sludge type were reviewed to assess their hazardous nature, based on the Alberta Hazardous Waste Regulation [Hazardous Chemicals Act (R.S.A. 1980, c. H-3, as amended)]. A summary of the assessment of each sludge is as follows:

i) Process Pond Sludge

All samples analyzed had relatively high oil and grease concentrations (11300 - 141000 ppm). As such, they could potentially be classified as hazardous wastes if it could be shown that the oil contained a TDGR Class 9.2 Dangerous Good (eg/ phenol, almost any aromatic hydrocarbon) at concentrations exceeding 0.01% by mass.

ii) Flare Knock-Out Sludge

One of the three samples analyzed had a flashpoint less than 61°C. As such, this samples would be classified as TDGR Class 3 Dangerous Good, and hence would also be classified as a hazardous waste. In addition, the high oil content which may be associated with the waste (the one sample analyzed had an oil and grease concentration of 520000 ppm) could also cause it to be classified as a hazardous waste if it was shown that a Class 9.2 Dangerous Good (e.g./phenol, almost any aromatic hydrocarbon) was present at concentrations exceeding 0.01% by mass.

iii) Flare Pit Sludge

All samples analyzed had relatively high oil and grease concentrations (4170 - 452000 ppm). As such, they could potentially be classified as hazardous wastes if it could be shown that the oil contained a TDGR Class 9.2 Good (eg/ phenol, almost any aromatic hydrocarbon) at concentrations exceeding 0.01% by mass.

iv) Treater Bottom Sludge

One of the three samples analyzed had a flashpoint less than 61°C. As such, this sample would be classified as TDGR Class 3 Dangerous Good, and hence would also be classified as a hazardous waste. In addition, the high oil content which may be associated with the waste (oil and grease concentrations ranged from 12700 to 26400 ppm) could also cause it to be classified as a hazardous waste if it was shown that a Class 9.2 Dangerous Good (e.g./phenol, almost any aromatic hydrocarbon) was present at concentrations exceeding 0.01% by mass.

v) Tank Bottom Sludge

One of the three samples analyzed had a flashpoint less than 61°C. As such, this sample would be classified as TDGR Class 3 Dangerous Good, and hence would also be classified as a hazardous waste. In addition, the high oil content which may be associated with the waste (oil and grease concentrations ranged from 3.6 to 10.5%) could also cause it to be classified as a hazardous waste if it was shown that a Class 9.2 Dangerous Good (e.g./phenol, almost any aromatic hydrocarbon) was present at concentrations exceeding 0.01% by mass.

v) Spill Material

One of the three samples analyzed was found to be a flammable solid. As such, this sample would be classified as TDGR Class 4 Dangerous Good, and hence would also be classified as a hazardous waste. In addition, the high oil content which may be associated with the

waste (oil and grease concentrations ranged from 1.0 to 13.5%) could also cause it to be classified as a hazardous waste if it was shown that a Class 9.2 Dangerous Good (e.g./phenol, almost any aromatic hydrocarbon) was present at concentrations exceeding 0.01% by mass.

The above assessment indicates that there is a possibility that all six sludges considered in this study, could potentially be classified as a hazardous waste. Therefore, it is recommended that the hazardous/non-hazardous classification of these wastes should be determined on an individual, case-by-case basis. In addition, given the high oil content of the sludges, it is also recommended that a more detailed organic analysis be undertaken to assist in the identification of TDGR Class 9.2 Dangerous Goods which may be contained in the sludges.

5.0 CONCLUSIONS

1. In general, the quality of the data obtained from the sampling and analytical program appears to be acceptable for the pre-screening of treatment technology options for the sludges.
2. In general, the analytical procedures used to measure the parameters considered in the project, appeared to be acceptable. An exception to this was the methods used to analyze oil and water contents in one of the tank bottom sludges.
3. All six (6) sludges considered in this study, are potentially hazardous based on the Alberta Hazardous Waste Regulation.
4. Leachates generated from the sludges considered in this study did not contain significant concentrations of metals, cyanides and nitrate/nitrite relative to the limits specified for a TDGR Class 9.3, Leachable Waste.

6.0 RECOMMENDATIONS

1. A minimum of two (2) litres of material should be collected for sludge analysis similar to that used in this project.
2. Because of the variability of physical and chemical properties for the different sludges, hazardous and non-hazardous classifications should be based on a case-by-case, site specific sampling and analytical program.
3. Due to the high oil content associated with the sludges considered in this study, a more detailed organic analysis should be carried out to determine the concentrations of selected TDGR Class 9.2 materials in the sludges prior to assigning a hazardous or non-hazardous classification.

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APPENDIX A

PHYSICAL AND CHEMICAL PARAMETER DATA BASE

TABLE 1: PROCESS POND SLUDGE (OILFIELD)

PARAMETER	1989/90 SAMPLING PROGRAM		
	SAMPLE #1	SAMPLE #2	SAMPLE #3
Biological Oxygen Demand (ppm)	10950	18600	20700
Total Organic Carbon (weight %)	2.8	12.6	10.5
Total Phosphorous (ppm)	377	890	1170
Total Kjeldahl Nitrogen (ppm)	396	1500	783
% Solids	73.3	40.6	26.6
% Water	25.3	38.4	55.5
Oil & Grease (ug/g)	11300	141000	59800
BTU Content (BTU/LB) as recieved basis	297	4532	1566
Total Sulphur (weight %)	0.04	1.18	0.62
Specific Gravity	1.77	1.22	1.14
pH	10.4	9.81	10.6
Electrical Conductance (umhos/cm)	1280	30000	48400
Particle size % Sand	54	12	22
Particle size % Silt	34	59	N.T.
Particle size % Clay	12	29	N.T.
Free Liquid (%)	0	0	0
Flashpoint (Centigrade)	N.A.	N.A.	N.A.
Flammability	no	no	no

Soluble Ions (On Total Sample Basis)			
Calcium (ppm)	120	2240	4400
Magnesium (ppm)	12	2.4	2.4
Sodium (ppm)	115	5130	7960
Potassium (ppm)	14.1	704	1570
Chloride (ppm)	192	6520	12800
Sulphate (ppm)	45.4	212	83.8
Bicarbonate (ppm)	154	260	135
Nitrate as N (ppm)	0.426	14	28
Sulfide (ppm)	80	6.4	8

Leachate Analysis			
Arsenic (mg/L)	0.01	0.014	0.0104
Barium (mg/L)	0.41	1.55	1.01
Boron (mg/L)	0.06	9.75	20.2
Cadmium (mg/L)	0.001	0.001	0.001
Chromium (mg/L)	0.003	0.002	0.001
Lead (mg/L)	0.02	0.01	0.01
Mercury (ug/L)	0.48	0.26	0.74
Selenium (mg/L)	0.0002	0.0002	0.0002
Cyanide (mg/L)	0.001	0.003	0.002
Nitrate/Nitrite as N (mg/L)	0.021	0.7	1.4

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SHEET 1 OF 2

TABLE 1: PROCESS POND SLUDGE (OILFIELD)

PARAMETER	STATISTICAL PARAMETERS			
	MEAN	MIN	MAX	STD. DEV.
Biological Oxygen Demand (ppm)	16750.00	10950	20700	4189.87
Total Organic Carbon (weight %)	8.63	2.8	12.6	4.21
Total Phosphorous (ppm)	812.33	377	1170	328.37
Total Kjeldahl Nitrogen (ppm)	893.00	396	1500	457.37
% Solids	46.83	26.6	73.3	19.57
% Water	39.73	25.3	55.5	12.37
Oil & Grease (ug/g)	70700	11300	141000	53507.82
BTU Content (BTU/LB) as recieved basis	2131.67	297	4532	1774.60
Total Sulphur (weight %)	0.61	0.04	1.18	0.47
Specific Gravity	1.38	1.14	1.77	0.28
pH	10.27	9.81	10.6	0.34
Electrical Conductance (umhos/cm)	26560.00	1280	48400	19389.84
Particle size % Sand	29.33	12	54	17.91
Particle size % Silt	46.50	34	59	12.50
Particle size % Clay	20.50	12	29	8.50
Free Liquid (%)	0.00	0	0	0.00
Flashpoint (Centigrade)	N.A.	N.A.	N.A.	N.A.
Flammability	N.A.	N.A.	N.A.	N.A.

Soluble Ions (On Total Sample Basis)				
Calcium (ppm)	2253.33	120	4400	1747.33
Magnesium (ppm)	5.60	2.4	12	4.53
Sodium (ppm)	4401.67	115	7960	3243.85
Potassium (ppm)	762.70	14.1	1570	636.55
Chloride (ppm)	6504.00	192	12800	5147.21
Sulphate (ppm)	113.73	45.4	212	71.23
Bicarbonate (ppm)	183.00	135	260	55.00
Nitrate as N (ppm)	14.14	0.426	28	11.26
Sulfide (ppm)	31.47	6.4	80	34.32

Leachate Analysis				
Arsenic (mg/L)	0.0115	0.01	0.014	0.0018
Barium (mg/L)	0.9900	0.41	1.55	0.4656
Boron (mg/L)	10.0033	0.06	20.2	8.2241
Cadmium (mg/L)	0.0010	0.001	0.001	0.0000
Chromium (mg/L)	0.0020	0.001	0.003	0.0008
Lead (mg/L)	0.0133	0.01	0.02	0.0047
Mercury (ug/L)	0.4933	0.26	0.74	0.1962
Selenium (mg/L)	0.0002	0.0002	0.0002	0.0000
Cyanide (mg/L)	0.0020	0.001	0.003	0.0008
Nitrate/Nitrite as N (mg/L)	0.7070	0.021	1.4	0.5630

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SHEET 2 OF 2

TABLE 2 - FLARE KNOCK-OUT SLUDGE (OILFIELD)

PARAMETER	1989/90 SAMPLING PROGRAM		
	SAMPLE #1	SAMPLE #2	SAMPLE #3
Biological Oxygen Demand (ppm)	1080	2940	4820
Total Organic Carbon (weight %)	53.9	36.3	1.43
Total Phosphorous (ppm)	190	0.1	1.88
Total Kjeldahl Nitrogen (ppm)	764	580	465
% Solids	1	6.4	7.9
% Water	40	87.1	82.2
Oil Content (ug/g)	520000	5812	64000
BTU Content (BTU/LB) as recieved basis	6410	19127	400
Total Sulphur (weight %)	0.27	0.52	0.05
Specific Gravity	0.9	0.8	1.1
pH	6.5	4.4	7.2
Electrical Conductance (umhos/cm)	40	140	135000
Particle size % Sand	I.S.	I.S.	I.S.
Particle size % Silt	I.S.	I.S.	I.S.
Particle size % Clay	I.S.	I.S.	I.S.
Free Liquid (%)	24	24	25
Flashpoint (Centigrade)	N.A.	-12	100
Flammability	no	N.A.	N.A.

Soluble Ions (On Total Sample Basis)			
Calcium (ppm)	20	40	11600
Magnesium (ppm)	12.2	12.2	1950
Sodium (ppm)	4.6	4.6	24000
Potassium (ppm)	1.56	0.78	2700
Chloride (ppm)	1.42	19.5	64600
Sulphate (ppm)	4.44	2.06	532
Bicarbonate (ppm)	10	5	206
Nitrate as N (ppm)	0.003	0.41	102
Sulfide (ppm)	64	470	64

Leachate Analysis			
Arsenic (mg/L)	0.003	N.T.	N.T.
Barium (mg/L)	0.17	N.T.	N.T.
Boron (mg/L)	1.02	N.T.	N.T.
Cadmium (mg/L)	0.001	N.T.	N.T.
Chromium (mg/L)	0.009	N.T.	N.T.
Lead (mg/L)	0.02	N.T.	N.T.
Mercury (ug/L)	0.14	N.T.	N.T.
Selenium (mg/L)	0.0002	N.T.	N.T.
Cyanide (mg/L)	0.001	N.T.	N.T.
Nitrate/Nitrite as N (mg/L)	0.003	N.T.	N.T.

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SHEET 1 OF 2

TABLE 2 - FLARE KNOCK-OUT SLUDGE (OILFIELD)

PARAMETER	STATISTICAL PARAMETERS			
	MEAN	MIN	MAX	STD. DEV.
Biological Oxygen Demand (ppm)	2946.67	1080	4820	1526.86
Total Organic Carbon (weight %)	30.54	1.43	53.9	21.80
Total Phosphorous (ppm)	63.99	0.1	190	89.10
Total Kjeldahl Nitrogen (ppm)	603.00	465	764	123.14
% Solids	5.10	1	7.9	2.96
% Water	69.77	40	87.1	21.14
Oil Content (ug/g)	196604.00	5812	520000	229906.05
BTU Content (BTU/LB) as recieved basis	8645.67	400	19127	7807.00
Total Sulphur (weight %)	0.28	0.05	0.52	0.19
Specific Gravity	0.93	0.8	1.1	0.12
pH	6.03	4.4	7.2	1.19
Electrical Conductance (umhos/cm)	45060.00	40	135000	63597.20
Particle size % Sand	N.A.	N.A.	N.A.	N.A.
Particle size % Silt	N.A.	N.A.	N.A.	N.A.
Particle size % Clay	N.A.	N.A.	N.A.	N.A.
Free Liquid (%)	24.33	24	25	0.47
Flashpoint (Centigrade)	N.A.	N.A.	N.A.	N.A.
Flammability	N.A.	N.A.	N.A.	N.A.

Soluble Ions (On Total Sample Basis)				
Calcium (ppm)	3886.67	20	11600	5454.16
Magnesium (ppm)	658.13	12.2	1950	913.49
Sodium (ppm)	8003.07	4.6	24000	11311.54
Potassium (ppm)	900.78	0.78	2700	1272.24
Chloride (ppm)	21540.31	1.42	64600	30447.80
Sulphate (ppm)	179.50	2.06	532	249.26
Bicarbonate (ppm)	73.67	5	206	93.60
Nitrate as N (ppm)	34.14	0.003	102	47.99
Sulfide (ppm)	199.33	64	470	191.39

Leachate Analysis				
Arsenic (mg/L)	0.0030	0.003	0.003	0.0000
Barium (mg/L)	0.1700	0.17	0.17	0.0000
Boron (mg/L)	1.0200	1.02	1.02	0.0000
Cadmium (mg/L)	0.0010	0.001	0.001	0.0000
Chromium (mg/L)	0.0090	0.009	0.009	0.0000
Lead (mg/L)	0.0200	0.02	0.02	0.0000
Mercury (ug/L)	0.1400	0.14	0.14	0.0000
Selenium (mg/L)	0.0020	0.002	0.0002	0.0000
Cyanide (mg/L)	0.0010	0.001	0.001	0.0000
Nitrate/Nitrite as N (mg/L)	0.0030	0.003	0.003	0.0000

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SHEET 2 OF 2

TABLE 3 - FLARE PIT SLUDGE (OILFIELD)

PARAMETER	1989/90 SAMPLING PROGRAM		
	SAMPLE #1	SAMPLE #2	SAMPLE #3
Biological Oxygen Demand (ppm)	2715	480	521
Total Organic Carbon (weight %)	32.4	18	1.67
Total Phosphorous (ppm)	363	350	355
Total Kjeldahl Nitrogen (ppm)	1860	980	7.85
% Solids	49.5	38.3	71.2
% Water	11.5	15.7	25.3
Oil Content (ug/g)	292000	452000	4170
BTU Content (BTU/LB) as recieved basis	1722	8219	94
Total Sulphur (weight %)	1.9	0.54	3.4
Specific Gravity	1.34	1.1	1.6
pH	7.68	5.6	5.9
Electrical Conductance (umhos/cm)	20200	3920	5680
Particle size % Sand	54	81	54
Particle size % Silt	31	5	32
Particle size % Clay	15	14	14
Free Liquid (%)	0	0	0
Flashpoint (Centigrade)	100	N.A.	N.A.
Flammability	no	no	no

Soluble Ions (On Total Sample Basis)			
Calcium (ppm)	320	260	640
Magnesium (ppm)	85	36.6	110
Sodium (ppm)	4160	398	211
Potassium (ppm)	158	46.9	81.3
Chloride (ppm)	1260	100	193
Sulphate (ppm)	103	185	3480
Bicarbonate (ppm)	173	75	10
Nitrate as N (ppm)	2.42	0.16	0.32
Sulfide (ppm)	1.9	145	186

Leachate Analysis			
Arsenic (mg/L)	0.0072	0.018	0.0008
Barium (mg/L)	0.37	0.01	0.05
Boron (mg/L)	1.78	0.13	0.11
Cadmium (mg/L)	0.001	0.007	0.007
Chromium (mg/L)	0.001	0.009	0.028
Lead (mg/L)	0.01	0.06	0.08
Mercury (ug/L)	0.18	0.1	0.1
Selenium (mg/L)	0.0002	0.002	0.0002
Cyanide (mg/L)	0.002	0.001	0.001
Nitrate/Nitrite as N (mg/L)	0.12	0.008	0.016

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SHEET 1 OF 2

TABLE 3 - FLARE PIT SLUDGE (OILFIELD)

PARAMETER	STATISTICAL PARAMETERS			
	MEAN	MIN	MAX	STD. DEV.
Biological Oxygen Demand (ppm)	1238.67	480	2715	1044.06
Total Organic Carbon (weight %)	17.36	1.67	32.4	12.55
Total Phosphorous (ppm)	356.00	350	363	5.35
Total Kjeldahl Nitrogen (ppm)	949.28	7.85	1860	756.45
% Solids	53.00	38.3	71.2	13.66
% Water	17.50	11.5	25.3	5.78
Oil Content (ug/g)	249390.00	4170	452000	185291.91
BTU Content (BTU/LB) as recieved basis	3345.00	94	8219	3509.94
Total Sulphur (weight %)	1.95	0.54	3.4	1.17
Specific Gravity	1.35	1.1	1.6	0.20
pH	6.39	5.6	7.68	0.92
Electrical Conductance (umhos/cm)	9933.33	3920	20200	7295.10
Particle size % Sand	63.00	54	81	12.73
Particle size % Silt	22.67	5	32	12.5
Particle size % Clay	14.33	14	15	0.47
Free Liquid (%)	0.00	0	0	0.00
Flashpoint (Centigrade)	N.A.	N.A.	N.A.	N.A.
Flammability	N.A.	N.A.	N.A.	N.A.

Soluble Ions (On Total Sample Basis)				
Calcium (ppm)	406.67	260	640	166.80
Magnesium (ppm)	77.20	36.6	110	30.47
Sodium (ppm)	1589.67	211	4160	1819.10
Potassium (ppm)	95.40	46.9	158	46.44
Chloride (ppm)	517.67	100	1260	526.28
Sulphate (ppm)	1256.00	103	3480	1572.96
Bicarbonate (ppm)	86.00	10	173	67.00
Nitrate as N (ppm)	0.97	0.16	2.42	1.03
Sulfide (ppm)	110.97	1.9	186	78.92

Leachate Analysis				
Arsenic (mg/L)	0.0087	0.0008	0.018	0.0071
Barium (mg/L)	0.1433	0.01	0.37	0.1611
Boron (mg/L)	0.6733	0.11	1.78	0.7826
Cadmium (mg/L)	0.0050	0.001	0.007	0.0028
Chromium (mg/L)	0.0127	0.001	0.028	0.0113
Lead (mg/L)	0.0500	0.01	0.08	0.0294
Mercury (ug/L)	0.1267	0.1	0.18	0.0377
Selenium (mg/L)	0.0008	0.0002	0.002	0.0008
Cyanide (mg/L)	0.0013	0.001	0.002	0.0005
Nitrate/Nitrite as N (mg/L)	0.0480	0.008	0.12	0.0510

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SHEET 2 OF 2

TABLE 4 - TREATER BOTTOM SLUDGE (OILFIELD)

PARAMETER	1989/90 SAMPLING PROGRAM		
	SAMPLE #1	SAMPLE #2	SAMPLE #3
Biological Oxygen Demand (ppm)	825	3360	2265
Total Organic Carbon (weight %)	25	66.8	21
Total Phosphorous (ppm)	6.8	11	336
Total Kjeldahl Nitrogen (ppm)	1320	2000	3000
% Solids	44	8.14	61.8
% Water	34.3	58.6	23.5
Oil Content (ug/g)	21700	554000	184000
BTU Content (BTU/LB) as recieved basis	6158	7287	2011
Total Sulphur (weight %)	5.79	1.2	0.5
Specific Gravity	1.27	1.01	1.56
pH	7.05	8.17	8.28
Electrical Conductance (umhos/cm)	26400	14200	12700
Particle size % Sand	17	I.S.	70
Particle size % Silt	58	I.S.	23
Particle size % Clay	25	I.S.	7
Free Liquid (%)	0	100	0
Flashpoint (Centigrade)	N.A.	+5	N.A.
Flammability	no	N.A.	no

Soluble Ions (On Total Sample Basis)			
Calcium (ppm)	680	180	320
Magnesium (ppm)	244	110	122
Sodium (ppm)	5680	2810	2240
Potassium (ppm)	188	54	165
Chloride (ppm)	9800	2470	2090
Sulphate (ppm)	248	16.2	17.7
Bicarbonate (ppm)	759	135	148
Nitrate as N (ppm)	6.4	3.5	3.14
Sulfide (ppm)	360	0.56	3.2

Leachate Analysis			
Arsenic (mg/L)	0.003	0.0003	0.0061
Barium (mg/L)	1.95	1.76	0.5
Boron (mg/L)	0.71	0.45	0.23
Cadmium (mg/L)	0.001	0.001	0.001
Chromium (mg/L)	0.001	0.001	0.001
Lead (mg/L)	0.02	0.02	0.01
Mercury (ug/L)	0.05	0.1	0.1
Selenium (mg/L)	0.0002	0.0002	0.0002
Cyanide (mg/L)	0.002	0.002	0.002
Nitrate/Nitrite as N (mg/L)	0.32	0.17	0.15

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SHEET 1 OF 3

(I.S. - Insufficient Sample / N.A. - Not Applicable / N.T. - Not Tested)

TABLE 4 - TREATER BOTTOM SLUDGE (OILFIELD)

PARAMETER	RESULTS FROM PREVIOUS DATA			
	SAMPLE #1	SAMPLE #2	SAMPLE #3	SAMPLE #4
Biological Oxygen Demand (ppm)				
Total Organic Carbon (weight %)				
Total Phosphorous (ppm)				
Total Kjeldahl Nitrogen (ppm)				
% Solids	75.8	59.1	15.8	79.1
% Water			20.3	12.1
Oil Content (ug/g)				
BTU Content (BTU/LB) as recieved basis				
Total Sulphur (weight %)				
Specific Gravity				
pH				
Electrical Conductance (umhos/cm)				
Particle size % Sand				
Particle size % Silt				
Particle size % Clay				
Free Liquid (%)				
Flashpoint (Centigrade)				
Flammability				

Soluble Ions (On Total Sample Basis)				
Calcium (ppm)				
Magnesium (ppm)				
Sodium (ppm)				
Potassium (ppm)				
Chloride (ppm)				
Sulphate (ppm)				
Bicarbonate (ppm)				
Nitrate as N (ppm)				
Sulfide (ppm)				

Leachate Analysis				
Arsenic (mg/L)				
Barium (mg/L)				
Boron (mg/L)				
Cadmium (mg/L)				
Chromium (mg/L)				
Lead (mg/L)				
Mercury (ug/L)				
Selenium (mg/L)				
Cyanide (mg/L)				
Nitrate/Nitrite as N (mg/L)				

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SHEET 2 OF 3

TABLE 4 - TREATER BOTTOM SLUDGE (OILFIELD)

PARAMETER	STATISTICAL PARAMETERS			
	MEAN	MIN	MAX	STD. DEV.
Biological Oxygen Demand (ppm)	2150.00	825	3360	1038.10
Total Organic Carbon (weight %)	37.60	21	66.8	20.71
Total Phosphorous (ppm)	117.93	6.8	336	154.21
Total Kjeldahl Nitrogen (ppm)	2106.67	1320	3000	689.99
% Solids	37.98	8.14	61.8	22.32
% Water	38.80	23.5	58.6	14.68
Oil Content (ug/g)	253233.33	21700	554000	222756.61
BTU Content (BTU/LB) as recieved basis	5152.00	2011	7287	2268.34
Total Sulphur (weight %)	2.50	0.5	5.79	2.35
Specific Gravity	1.28	1.01	1.56	0.22
pH	7.83	7.05	8.28	0.56
Electrical Conductance (umhos/cm)	17766.67	12700	26400	6135.33
Particle size % Sand	29.00	0	70	29.81
Particle size % Silt	27.00	0	58	23.85
Particle size % Clay	10.67	0	25	10.53
Free Liquid (%)	33.33	0	100	47.14
Flashpoint (Centigrade)	N.A.	N.A.	N.A.	N.A.
Flammability	N.A.	N.A.	N.A.	N.A.

Soluble Ions (On Total Sample Basis)				
Calcium (ppm)	393.33	180	680	210.61
Magnesium (ppm)	158.67	110	244	60.54
Sodium (ppm)	3576.67	2240	5680	1505.38
Potassium (ppm)	135.67	54	188	58.51
Chloride (ppm)	4786.67	2090	9800	3548.35
Sulphate (ppm)	93.97	16.2	248	108.92
Bicarbonate (ppm)	347.33	135	759	291.14
Nitrate as N (ppm)	4.35	3.14	6.4	1.46
Sulfide (ppm)	121.25	0.56	360	168.82

Leachate Analysis				
Arsenic (mg/L)	0.0031	0.0003	0.0061	0.0024
Barium (mg/L)	1.4033	0.5	1.95	0.6434
Boron (mg/L)	0.4633	0.23	0.71	0.1962
Cadmium (mg/L)	0.0008	0	0.001	0.0000
Chromium (mg/L)	0.0008	0	0.001	0.0000
Lead (mg/L)	0.0167	0.01	0.02	0.0047
Mercury (ug/L)	0.0833	0.05	0.1	0.0236
Selenium (mg/L)	0.0002	0	0.0002	0.0000
Cyanide (mg/L)	0.0015	0	0.002	0.0000
Nitrate/Nitrite as N (mg/L)	0.2133	0.15	0.32	0.0759

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SHEET 3 OF 3

TABLE 5 - TANK BOTTOM SLUDGE (OILFIELD)

PARAMETER	1989/90 SAMPLING PROGRAM		
	SAMPLE #1	SAMPLE #2	SAMPLE #3
Biological Oxygen Demand (ppm)	19.5	354	2940
Total Organic Carbon (weight %)	9.5	9.2	5.91
Total Phosphorous (ppm)	13.2	3	226
Total Kjeldahl Nitrogen (ppm)	1470	524	235
% Solids	49.1	0.7	80.5
% Water	40.4	N.T.	9.85
Oil Content (%)	10.5	N.T.	36
BTU Content (BTU/LB) as recieved basis	3756	886	1341
Total Sulphur (weight %)	1.66	0.62	0.33
Specific Gravity	1.31	0.99	1.34
pH	7.73	6.89	11.3
Electrical Conductance (umhos/cm)	2420	28000	14600
Particle size % Sand	7	I.S.	78
Particle size % Silt	85	I.S.	15
Particle size % Clay	8	I.S.	7
Free Liquid (%)	0	100	0
Flashpoint (Centigrade)	N.A.	24	N.A.
Flammability	no	N.A.	no

Soluble Ions (On Total Sample Basis)			
Calcium (ppm)	40	680	500
Magnesium (ppm)	12.2	171	12
Sodium (ppm)	540	5640	2750
Potassium (ppm)	9.38	179	81.3
Chloride (ppm)	274	9520	2300
Sulphate (ppm)	97.4	24.8	80
Bicarbonate (ppm)	950	361	22.6
Nitrate as N (ppm)	0.1	6.4	3.84
Sulfide (ppm)	3400	360	1.2

Leachate Analysis			
Arsenic (mg/L)	0.0069	N.T.	0.016
Barium (mg/L)	22.3	N.T.	1.6
Boron (mg/L)	0.32	N.T.	0.88
Cadmium (mg/L)	0.001	N.T.	0.001
Chromium (mg/L)	0.001	N.T.	0.001
Lead (mg/L)	0.01	N.T.	0.01
Mercury (ug/L)	0.05	N.T.	0.26
Selenium (mg/L)	0.0002	N.T.	0.0002
Cyanide (mg/L)	0.002	N.T.	0.002
Nitrate/Nitrite as N (mg/L)	0.005	N.T.	0.19

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SHEET 1 OF 2

(I.S. - Insufficient Sample / N.A. - Not Applicable / N.T. - Not Tested)

TABLE 5 - TANK BOTTOM SLUDGE (OILFIELD)

PARAMETER	STATISTICAL PARAMETERS			
	MEAN	MIN	MAX	STD. DEV.
Biological Oxygen Demand (ppm)	1104.50	19.5	2940	1305.06
Total Organic Carbon (weight %)	8.20	5.91	9.5	1.63
Total Phosphorous (ppm)	80.73	3	226	102.80
Total Kjeldahl Nitrogen (ppm)	743.00	235	1470	527.43
% Solids	43.43	0.7	80.5	32.82
% Water	16.75	0	40.4	17.20
Oil Content (%)	15.50	0	36	15.12
BTU Content (BTU/LB) as recieved basis	1994.33	886	3756	1259.46
Total Sulphur (weight %)	0.87	0.33	1.66	0.57
Specific Gravity	1.21	0.99	1.34	0.16
pH	8.64	6.89	11.3	1.91
Electrical Conductance (umhos/cm)	15006.67	2420	28000	10446.95
Particle size % Sand	28.33	0	78	35.24
Particle size % Silt	33.33	0	85	37.04
Particle size % Clay	5.00	0	8	3.56
Free Liquid (%)	33.33	0	100	47.14
Flashpoint (Centigrade)	N.A.	N.A.	N.A.	N.A.
Flammability	N.A.	N.A.	N.A.	N.A.

Soluble Ions (On Total Sample Basis)				
Calcium (ppm)	406.67	40	680	269.49
Magnesium (ppm)	65.07	12	171	74.91
Sodium (ppm)	2976.67	540	5640	2088.23
Potassium (ppm)	89.89	9.38	179	69.51
Chloride (ppm)	4031.33	274	9520	3968.23
Sulphate (ppm)	67.40	24.8	97.4	30.95
Bicarbonate (ppm)	444.53	22.6	950	383.19
Nitrate as N (ppm)	3.45	0.1	6.4	2.59
Sulfide (ppm)	1253.73	1.2	3400	1524.69

Leachate Analysis				
Arsenic (mg/L)	0.01	0	0.016	0.01
Barium (mg/L)	7.97	0	22.3	0.00
Boron (mg/L)	0.40	0	0.88	0.36
Cadmium (mg/L)	0.00	0	0.001	0.00
Chromium (mg/L)	0.00	0	0.001	0.00
Lead (mg/L)	0.01	0	0.01	0.00
Mercury (ug/L)	0.10	0	0.26	0.11
Selenium (mg/L)	0.00	0	0.0002	0.00
Cyanide (mg/L)	0.00	0	0.002	0.00
Nitrate/Nitrite as N (mg/L)	0.07	0	0.19	0.09

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SHEET 2 OF 2

TABLE 6 - SPILL MATERIAL SLUDGE (OILFIELD)

PARAMETER	1989/90 SAMPLING PROGRAM		
	SAMPLE #1	SAMPLE #2	SAMPLE #3
Biological Oxygen Demand (ppm)	1557	851	741
Total Organic Carbon (weight %)	14	4.3	3.8
Total Phosphorous (ppm)	97.6	119	185
Total Kjeldahl Nitrogen (ppm)	956	2000	1520
% Solids	85.9	89	98.4
% Water	0.6	8	0.6
Oil Content (%)	13.5	3	1
BTU Content (BTU/LB) as recieved basis	1300	1348	1404
Total Sulphur (weight %)	0.38	0.21	0.19
Specific Gravity	1.04	1.14	1.05
pH	7.25	7.24	7.29
Electrical Conductance (umhos/cm)	7940	27400	11520
Particle size % Sand	61	41	43
Particle size % Silt	28	32	34
Particle size % Clay	11	27	23
Free Liquid (%)	0	0	0
Flashpoint (Centigrade)	N.A.	N.A.	N.A.
Flammability	yes	no	no

Soluble Ions (On Total Sample Basis)			
Calcium (ppm)	120	300	160
Magnesium (ppm)	36.6	171	48.4
Sodium (ppm)	1690	6140	2440
Potassium (ppm)	39.2	10.8	49.2
Chloride (ppm)	2020	10160	3600
Sulphate (ppm)	10160	924	872
Bicarbonate (ppm)	384	786	775
Nitrate as N (ppm)	10	10	10
Sulfide (ppm)	80	40	80

Leachate Analysis			
Arsenic (mg/L)	N.T.	0.0084	0.0035
Barium (mg/L)	N.T.	0.74	0.35
Boron (mg/L)	N.T.	0.96	0.18
Cadmium (mg/L)	N.T.	0.001	0.001
Chromium (mg/L)	N.T.	0.001	0.001
Lead (mg/L)	N.T.	0.001	0.001
Mercury (ug/L)	N.T.	0.25	0.21
Selenium (mg/L)	N.T.	0.0002	0.0002
Cyanide (mg/L)	N.T.	0.001	0.005
Nitrate/Nitrite as N (mg/L)	N.T.	0.5	0.5

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SHEET 1 OF 2

TABLE 6 - SPILL MATERIAL SLUDGE (OILFIELD)

PARAMETER	STATISTICAL PARAMETERS			
	MEAN	MIN	MAX	STD. DEV.
Biological Oxygen Demand (ppm)	1049.67	741	1557	361.54
Total Organic Carbon (weight %)	7.37	3.8	14	4.69
Total Phosphorous (ppm)	133.87	97.6	185	37.20
Total Kjeldahl Nitrogen (ppm)	1492.00	956	2000	426.67
% Solids	91.10	85.9	98.4	5.31
% Water	3.07	0.6	8	3.49
Oil Content (%)	5.83	1	13.5	5.48
BTU Content (BTU/LB) as recieved basis	1350.67	1300	1404	42.50
Total Sulphur (weight %)	0.26	0.19	0.38	0.09
Specific Gravity	1.08	1.04	1.14	0.04
pH	7.26	7.24	7.29	0.02
Electrical Conductance (umhos/cm)	15620.00	7940	27400	8456.97
Particle size % Sand	48.33	41	61	8.99
Particle size % Silt	31.33	28	34	2.49
Particle size % Clay	20.33	11	27	6.80
Free Liquid (%)	0.00	0	0	0.00
Flashpoint (Centigrade)	N.A.	N.A.	N.A.	N.A.
Flammability	N.A.	N.A.	N.A.	N.A.

Soluble Ions (On Total Sample Basis)				
Calcium (ppm)	193.33	120	300	77.17
Magnesium (ppm)	85.33	36.6	171	60.77
Sodium (ppm)	3423.33	1690	6140	1945.22
Potassium (ppm)	33.07	10.8	49.2	16.27
Chloride (ppm)	5260.00	2020	10160	3524.35
Sulphate (ppm)	3985.33	872	10160	4366.20
Bicarbonate (ppm)	648.33	384	786	186.97
Nitrate as N (ppm)	10.00	10	10	0.00
Sulfide (ppm)	66.67	40	80	18.86

Leachate Analysis				
Arsenic (mg/L)	0.00	0	0.0084	0.00
Barium (mg/L)	0.36	0	0.74	0.30
Boron (mg/L)	0.38	0	0.96	0.42
Cadmium (mg/L)	0.00	0	0.001	0.00
Chromium (mg/L)	0.00	0	0.001	0.00
Lead (mg/L)	0.00	0	0.001	0.00
Mercury (ug/L)	0.15	0	0.25	0.11
Selenium (mg/L)	0.00	0	0.0002	0.00
Cyanide (mg/L)	0.00	0	0.005	0.00
Nitrate/Nitrite as N (mg/L)	0.33	0	0.5	0.24

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SHEET 2 OF 2

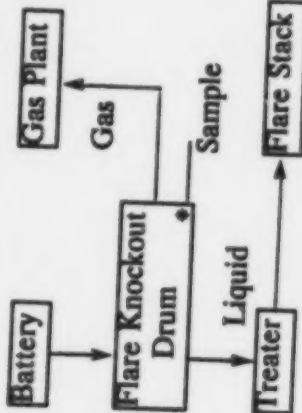
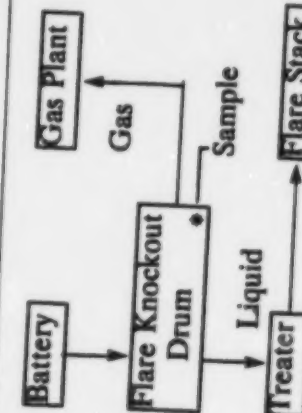
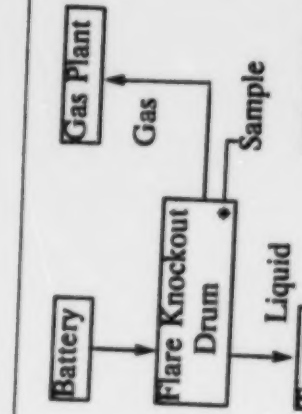
APPENDIX B
SAMPLING REPORTS

PROCESS POND SLUDGE (OILFIELD)
Identification Number: 1

CPA OILFIELD SLUDGE TREATMENT TECHNOLOGY ASSESSMENT PROJECT
SAMPLING REPORT

Sample # Plant Specifics	1	2	3
Composite of	3 Samples	5 Samples	5 Samples
Date Sampled	24 January 1990	24 January 1990	24 January 1990
Analysis Began		6 March 1990	6 March 1990
Analysis Complete		28 March 1990	28 March 1990
Sample Location	Waste collection pond.	Obtained from contractor operated collection pond used to store waste from oilfield collection pond prior to recycling operation.	Pond on oilfield lease.
Sampling Technique	Access through a manhole. The pit is 4 m deep. Samples taken by scooping sludge from the bottom of the pit with a metal cylinder welded to a long pipe. Three samples were taken from about 1 m below the surface of the pond.	A long handled shovel was used to take a composite sample.	A backhoe was used to get material from five points in the pond and a composite sample was taken.
Visual Description	Black, oily with a grease-like consistency.	Fairly coarse material, partially frozen.	Greyish color with a little oil.
Sample Source Diagram	<pre> graph TD TB[Tank Bottoms] --> PP[Process Pond] TrB[Treater Bottoms] --> PP PP -- Samples --> S[Samples] PP -- Water --> W[Water] W --> DS[Disp. Well] DS -- Oil/Solids --> R[Reclaimer] </pre>	<pre> graph TD TrB[Treater Bottoms] --> PP[Process Pond] TB[Tank Bottoms] --> PP PP -- Oil --> O[Oil: Recycling] PP -- Sludge --> SD[Sludge: Disposal] O --> CS[Composite Sample] SD --> CS </pre>	<pre> graph TD TB[Tank Bottoms] --> VT[Vacuum Truck] PW[Paraffin & Wax] --> VT VT --> PP[Process Pond] PP -- Samples --> S[Samples] S --> R[Reclaimer] </pre>

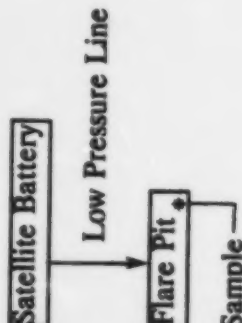
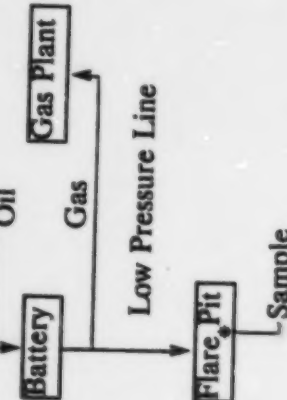
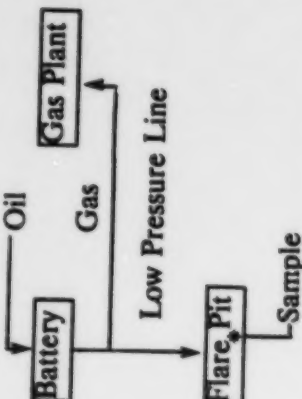
FLARE KNOCKOUT SLUDGE (OILFIELD) CPA OILFIELD SLUDGE TREATMENT TECHNOLOGY ASSESSMENT PROJECT
Identification Number: 2 **SAMPLING REPORT**

Sample # Plant Specifics	1	2	3
Composite of	1 Sample	1 Sample	1 Sample
Date Sampled	16 March 1990	16 March 1990	13 March 1990
Analysis Began	6 April 1990	6 April 1990	6 April 1990
Analysis Complete	23 April 1990	23 April 1990	23 April 1990
Sample Location	Flare knockout drum.	Flare knockout drum.	Flare knockout tank.
Sampling Technique	Valve on base of tank used to draw sample directly into sample container.	Taken from valve on base of flare knockout drum and transferred directly into the sample container.	Valve on base of tank used to draw a sample directly into the sample container.
Visual Description	Fairly clear liquid. Slight odor.	Light oily liquid with a strong odor.	Thick creamy colored sludge.
Sample Source Diagram	 <pre> graph TD Battery --> FKD[Flare Knockout Drum] FKD -- Gas --> GP[Gas Plant] FKD -- Sample --> FS[Flare Stack] FKD -- Liquid --> Treater </pre>	 <pre> graph TD Battery --> FKD[Flare Knockout Drum] FKD -- Gas --> GP[Gas Plant] FKD -- Sample --> FS[Flare Stack] FKD -- Liquid --> Treater </pre>	 <pre> graph TD Battery --> FKD[Flare Knockout Drum] FKD -- Gas --> GP[Gas Plant] FKD -- Sample --> FS[Flare Stack] FKD -- Liquid --> Treater </pre>

FLARE PTT SLUDGE (OILFIELD)

Identification Number: 3

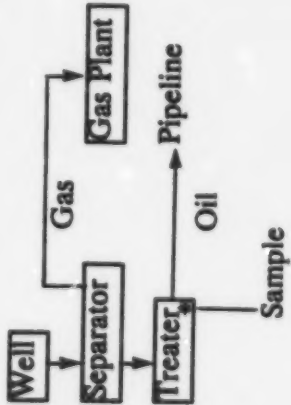
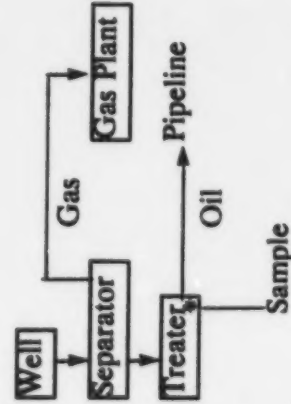
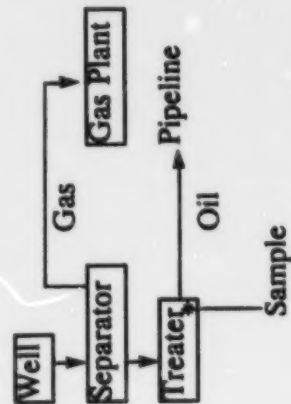
CPA OILFIELD SLUDGE TREATMENT TECHNOLOGY ASSESSMENT PROJECT SAMPLING REPORT

Sample # Plant Specifics	1	2	3
Composite of	1 Sample	1 Sample	1 Sample
Date Sampled	19 March 1990	19 March 1990	2 March 1990
Analysis Began	6 April 1990	6 April 1990	6 March 1990
Analysis Complete	23 April 1990	23 April 1990	28 March 1990
Sample Location	Flare pit at a satellite battery.	Flare pit at Y-battery.	Flare pit at oil battery.
Sampling Technique	Sample taken directly from pit using a spatula.	Sample taken directly out of the pit using a spatula.	Sample taken out of flare pit and transferred to sample container.
Visual Description	Greyish color.	Black and oily.	Fairly oily.
Sample Source Diagram	 <pre> graph TD SB[Satellite Battery] --> FP[Flare Pit] FP --> S[Sample] </pre>	 <pre> graph TD B[Battery] --> FP[Flare Pit] B --> GP[Gas Plant] FP --> LPL[Low Pressure Line] GP --> LPL LPL --> S[Sample] </pre>	 <pre> graph TD B[Battery] --> FP[Flare Pit] B --> GP[Gas Plant] FP --> LPL[Low Pressure Line] GP --> LPL LPL --> S[Sample] </pre>

TREATER BOTTOM SLUDGE (OILFIELD)

CPA OILFIELD SLUDGE TREATMENT TECHNOLOGY ASSESSMENT PROJECT SAMPLING REPORT

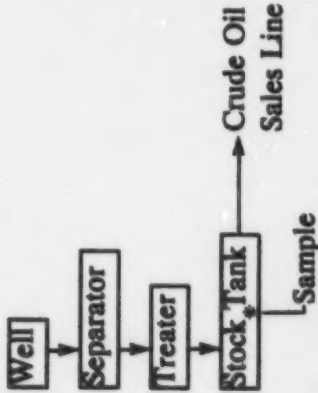
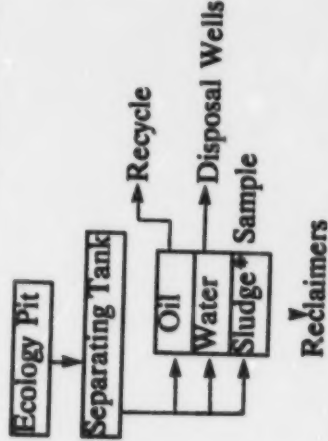
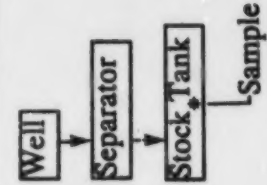
Identification Number: 4

Sample # Plant Specifics	1	2	3
Composite of	1 Sample	1 Sample	1 Sample
Date Sampled	1 October 1989	31 January 1990	1 February 1990
Analysis Began	9 February 1990	6 March 1990	6 March 1990
Analysis Complete	26 February 1990	28 March 1990	28 March 1990
Sample Location	Treater at oilfield battery.	Sample obtained from a treater at an oilfield battery.	Sample taken from the bottom of the treater at the oilfield battery.
Sampling Technique	Sample taken by operator when the treater was opened and cleaned. Sample put directly into the sample container.	Treater bottom sludge is pumped through a line from the treater to a desand pit. The sample was obtained by opening a valve on this line.	Treater bottom sludge is pumped through a line from the treater to a desand pit. The sample was obtained by opening a valve on this line.
Visual Description	Dark liquid (not as viscous as tank bottoms).	Black with a treacle consistency.	Black and sandy. Semi-solid.
Sample Source Diagram	 <pre> graph TD Well[Well] --> Separator[Separator] Separator -- Gas --> GasPlant[Gas Plant] Separator --> Treater[Treater] Treater -- Sample --> Sample[Sample] Treater -- Oil --> Pipeline[Pipeline] </pre>	 <pre> graph TD Well[Well] --> Separator[Separator] Separator -- Gas --> GasPlant[Gas Plant] Separator --> Treater[Treater] Treater -- Sample --> Sample[Sample] Treater -- Oil --> Pipeline[Pipeline] </pre>	 <pre> graph TD Well[Well] --> Separator[Separator] Separator -- Gas --> GasPlant[Gas Plant] Separator --> Treater[Treater] Treater -- Sample --> Sample[Sample] Treater -- Oil --> Pipeline[Pipeline] </pre>

TANK BOTTOM SLUDGE (OILFIELD)

Identification Number: 5

CPA OILFIELD SLUDGE TREATMENT TECHNOLOGY ASSESSMENT PROJECT SAMPLING REPORT

Sample # Plant Specifics	1	2	3
Composite of	1 Sample	1 Sample	1 Sample
Date Sampled	7 November 1989	11 December 1989	12 February 1990
Analysis Began	9 February 1990	9 February 1990	6 March 1990
Analysis Complete	26 February 1990	26 February 1990	28 March 1990
Sample Location	Empty crude oil storage tank at a conventional oil production battery.	Separating tank on oilwell lease.	Storage tank on oilwell lease.
Sampling Technique	Manway at the base of the tank was removed and a shovel used to remove sludge from under a 125 mm layer of oil residue. A 500 ml sample was transferred to a glass sample bottle.	Tank in the process of being cleaned. Sample scooped up with a shovel and transferred to a sample container.	Tank in the process of being cleaned. Sample scooped up with a shovel and transferred to sample bottle.
Visual Description	Black color. Consisted of an oily fluid phase and a black semi-solid phase.	Dark viscous liquid.	Dark, viscous material.
Sample Source Diagram	 <pre> graph TD Well[Well] --> Separator[Separator] Separator --> Treater[Treater] Treater --> StockTank[Stock Tank] StockTank --> Sample[Sample] StockTank --> CrudeOil[Crude Oil Sales Line] </pre>	 <pre> graph TD EcologyPit[Ecology Pit] --> SeparatingTank[Separating Tank] SeparatingTank --> Oil[Oil] SeparatingTank --> Water[Water] SeparatingTank --> Sludge[Sludge] Sludge --> Reclaimers[Reclaimers] Oil --> Recycle[Recycle] Water --> Recycle Sludge --> Sample[Sample] </pre>	 <pre> graph TD Well[Well] --> Separator[Separator] Separator --> StockTank[Stock Tank] StockTank --> Sample[Sample] </pre>

SPILL MATERIAL SLUDGE (OILFIELD) **CPA OILFIELD SLUDGE TREATMENT TECHNOLOGY ASSESSMENT PROJECT**
Identification Number: 6 **SAMPLING REPORT**

Sample # Plant Specifics	1	2	3
Composite of	1 Sample	1 Sample	1 Sample
Date Sampled	1 February 1990	1 February 1990	15 January 1990
Analysis Began	9 February 1990	9 February 1990	9 February 1990
Analysis Complete	26 February 1990	26 February 1990	26 February 1990
Sample Location	Oilfield ecology pit dedicated to spill material.	Oilfield battery.	Oilfield battery.
Sampling Technique	All spill material is brought by truck and put in a bunker/ecology pit. The sample was taken from this pit. As the material was solid various samples were chosen along the side of the pit.	Material collected by shovel and transferred to glass sample bottle.	Material collected by shovel and transferred to glass sample bottle.
Visual Description	Dark color and sandy.	Light brown, sandy silt.	Light brown, sandy.
Sample Source Diagram			

APPENDIX C
QUALITY CONTROL REPORTS

QUALITY CONTROL RESULTS
David Bromley Engineering Ltd.

Sample #2608, 2246, 2874, 317

Parameter: Total Phosphorus by ICP

Standard Check Solution (prepared by QA/QC)

Date	Value	Theoretical Value	% Recovery
Jan. 1990	507 ug/g	540 ug/g	93.8
Feb. 15/90	460	540	85.2

Check Sample was National Bureau of Standards Standard Reference Material 1646

QUALITY CONTROL RESULTS
David Bromley Engineering Ltd.

Sample #2608, 2246, 2874, 317

Parameter: Total Organic Carbon in soil			
Standard Check Solution (prepared by QA/GC)			
Date	Value	Theoretical Value	% Recovery
Jan. 9/90	0.88%	0.84%	105.
	0.82	0.84	98.
Feb. 14/90	0.89	0.87	102.

QUALITY CONTROL RESULTS
David Bromley Engineering Ltd.

Sample #2608, 2246, 2874, 317

Parameter: Total Sulphur (Leco) Units - wt. %

Duplicates

Date	Sample #	Orig. Value	Dupl. Value	Difference	Allow. Diff.	Acceptable
Jan. 25/90	2608-3	<0.1	<0.1	0.		
	2608-14	1.18	1.34	0.16		
	2608-17	2.12	2.03	0.09		
	2246-1	0.38	0.36	0.02		
Apr. 10/90	317-4	.54	.64	0.10		

QUALITY CONTROL RESULTS
David Bromley Engineering Ltd.

Sample #2608, 2246, 2874, 317

Parameter: Total Kjeldahl Nitrogen

Standard Check Solution (prepared by QA/QC)

Date	Value	Theoretical Value	% Recovery
Jan. 23/90	0.56	0.57	98.2
Feb. 15/90	0.55	0.57	110.
Apr. 11/90	0.60	0.57	105.3

Analyst-Prepared Spikes

Date	Sample	Value	Theoretical Value	% Recovery
Jan. 23/90	2608-18	1.26	1.17	108.
Feb. 15/90	2911-8	0.53	0.53	100.
Apr. 11/90	302-3D	0.98	1.00	98.0

Duplicates

Date	Sample #	Orig. Value	Dupl. Value	Difference	Allow. Diff.	Acceptable
Jan. 23/90	2608-14	0.16	0.15	0.01	0.03	yes
	2608-18	0.15	0.13	0.02	0.03	yes
Feb. 15/90	2911-7	0.70	0.66	0.04	0.07	yes
Apr. 11/90	330-1	11.0	12.0	1.0	2.0	yes

QUALITY CONTROL RESULTS
David Bromley Engineering Ltd.

Sample #2608, 2246, 317

Parameter: pH

Duplicates

Date	Sample #	Orig. Value	Dupl. Value	Difference	Allow. Diff.	Acceptable
Jan. 15/90	2608-10	7.40	7.41	0.01	0.1	yes
	2608-17	7.34	7.36	0.01	0.1	yes
APr. 10/90	317-10	8.38	8.29	0.09	0.1	

QUALITY CONTROL RESULTS
David Bromley Engineering Ltd.

Sample #2608-2246, 2874, 317

Parameter: Conductivity (umhos)

Duplicates

Date	Sample #	Orig. Value	Dupl. Value	Difference	Allow. Diff.	Acceptable
Jan. 15/90	2608-10	2430	2490	60.	150.	yes
Feb. 5/90	2874-5	5340	5440	100.	150.	yes
Apr. 11/90	317-10	1560	1440	120.	150.	yes

QUALITY CONTROL RESULTS
David Bromley Engineering Ltd.

Sample #2608, 2246, 2874, 317

Parameter: Calcium (ppm)

Standard Check Solution (prepared by QA/QC)

Date	Value	Theoretical Value	% Recovery
Jan. 17/90	40.	40.	100.
Feb. 5/90	42.	40.	105.
Apr. 12/90	36.	40.	90.

Duplicates

Date	Sample #	Orig. Value	Dupl. Value	Difference	Allow. Diff.	Acceptable
Jan. 17/90	2608-10	340.	300.	40.		
	2608-17	720.	720.	0.		
Feb. 5/90	2874-5	160.	240.	80.		
Apr. 12/90	317-10	20.	40.	20.		

QUALITY CONTROL RESULTS
David Bromley Engineering Ltd.

Sample #2608, 2246, 2874, 317

Parameter: Magnesium (ppm)

Standard Check Solution (prepared by QA/QC)

Date	Value	Theoretical Value	% Recovery
Jan. 17/90	22.	20.	110.
Feb. 5/90	19.5	20.	97.
Apr. 12/90	19.5	20.	97.5

Duplicates

Date	Sample #	Orig. Value	Dupl. Value	Difference	Allow. Diff.	Acceptable
Jan. 17/90	2608-10	122.	110.	12.		
	2608-17	73.2	73.2	0.		
Feb. 5/90	2874-5	49.	49.	0.		
Apr. 12/90	317-10	10.9	12.2	1.3		

QUALITY CONTROL RESULTS
David Bromley Engineering Ltd.

Sample #2608, 2246, 2874, 317

Parameter: Sodium (ppm)

Standard Check Solution (prepared by QA/QC)

Date	Value	Theoretical Value	% Recovery
Jan. 16/90	687.	641.	107.
Feb. 2/90	678.	641.	106.
Apr. 12/90	692.	641.	108.

Duplicates

Date	Sample #	Orig. Value	Dupl. Value	Difference	Allow. Diff.	Acceptable
Jan. 16/90	2608-10	742.	742.	0.		
	2608-17	1928.	1840.	88.		
Feb. 2/90	2874-5	160.	160.	0.		
Apr. 12/90	317-10	183.	220.	37.		

QUALITY CONTROL RESULTS
David Bromley Engineering Ltd.

Sample #2608, 2246, 2874, 317

Parameter: Potassium (ppm)

Standard Check Solution (prepared by QA/QC)

Date	Value	Theoretical Value	% Recovery
Jan. 16/90	40.2	39.1	103.
Feb. 2/90	39.9	39.1	102.
Apr. 12/90	43.4	39.1	111.

Duplicates

Date	Sample #	Orig. Value	Dupl. Value	Difference	Allow. Diff.	Acceptable
Jan. 16/90	2608-10	45.4	46.9	1.5		
	2608-17	205.	198.	7.		
Feb. 2/90	2874-5	10.9	10.9	0.		
Apr. 12/90	317-10	10.9	12.2	1.3		

QUALITY CONTROL RESULTS
David Bromley Engineering Ltd.

Sample #2608, 2246, 2874, 317

Parameter: Chloride by Ion Chromatography

Standard Check Solution (prepared by QA/QC)

Date	Value	Theoretical Value	% Recovery
Feb. 7/90	7.6	8.0	95.0
Feb. 6/90	7.7	8.0	96.2
Apr. 16/90	7.9	8.0	98.7

Analyst-Prepared Spikes

Date	Sample	Value	Theoretical Value	% Recovery
Feb. 7/90	1874-9	7.7	7.7	100.
Feb. 6/90	2417-20	6.9	6.8	101.
Apr. 16/90	372-4	8.29	8.23	100.7

Duplicates

Date	Sample #	Orig. Value	Dupl. Value	Difference	Allow. Diff.	Acceptable
Feb. 7/90	2874-9	5.4	5.4	0.	0.9	yes
Feb. 6/90	2417-20	3.5	3.6	0.1	0.6	yes
Apr. 16/90	372-3	29.0	28.8	0.2	1.3	yes
	317-10	33.8	33.3	0.5	1.3	yes

QUALITY CONTROL RESULTS
David Bromley Engineering Ltd.

Sample #2608, 2246, 2874, 317

Parameter: Sulphate by Ion Chromatography

Standard Check Solution (prepared by QA/QC)

Date	Value	Theoretical Value	% Recovery
Feb. 7/90	5.9	6.0	98.3
Feb. 6/90	6.2	6.0	103.
Apr. 16/90	5.9	6.0	98.3

Analyst-Prepared Spikes

Date	Sample	Value	Theoretical Value	% Recovery
Feb. 7/90	2874-9	28.0	27.8	100.7
Feb. 6/90	2417-20	29.3	29.3	100.
Apr. 16/90	372-4	33.3	33.3	100.0

Duplicates

Date	Sample #	Orig. Value	Dupl. Value	Difference	Allow. Diff.	Acceptable
Feb. 7/90	2874-9	30.0	30.5	0.5	2.5	yes
Feb. 6/90	2417-20	33.6	34.2	0.6	2.5	yes
Apr. 16/90	317-10	65.4	61.4	4.	4.8	yes

QUALITY CONTROL RESULTS
David Bromley Engineering Ltd.

Sample #2608, 2246, 2874, 317

Parameter: Bicarbonate

Duplicates

Date	Sample #	Orig. Value	Dupl. Value	Difference	Allow. Diff.	Acceptable
Jan. 18/90	2608-10	455.	412.	43.		
Feb. 5/90	2874-5	3080.	2920.	160.		
Apr. 11/90	317-10	335.	345.	10.		

QUALITY CONTROL RESULTS
David Bromley Engineering Ltd.

Sample #2608, 2246, 2874, 317

Parameter: Nitrate

Standard Check Solution (prepared by QA/QC)

Date	Value	Theoretical Value	% Recovery
Feb. 7/90	0.071	0.068	104.

Analyst-Prepared Spikes

Date	Sample	Value	Theoretical Value	% Recovery
Feb. 7/90	2874-6	0.58	0.56	96.5

Duplicates

Date	Sample #	Orig. Value	Dupl. Value	Difference	Allow. Diff.	Acceptable
Feb. 7/90	2874-6	0.210	0.198	0.012		

QUALITY CONTROL RESULTS
David Bromley Engineering Ltd.

Sample #2608, 2246, 2874, 317

Parameter: Sulphide (Iodometric Method)

Standard Check Solution (prepared by QA/QC)

Date	Value	Theoretical Value	% Recovery
Feb. 14/90	92.	92.	100.
Apr. 10/90	69.1	73.3	94.2

Duplicates

Date	Sample #	Orig. Value	Dupl. Value	Difference	Allow. Diff.	Acceptable
Feb. 14/90	3002-2	1760.	1760.	0.		
Apr. 10/90	317-9	307.8	307.8	0.		

QUALITY CONTROL RESULTS
David Bromley Engineering Ltd.

Sample #2608, 2246, 317

Parameter: Cyanide

Standard Check Solution (prepared by QA/QC)

Date	Value	Theoretical Value	% Recovery
Jan. 24/90	0.046	0.043	107.
	0.044	0.043	102.3
Feb. 6/90	0.042	0.043	97.6
	0.043	0.043	100.
Apr. 11/90	0.050	0.051	98.0
	0.051	0.051	100.0

Analyst-Prepared Spikes

Date	Sample	Value	Theoretical Value	% Recovery
Jan. 24/90	2823-11	0.024	0.024	100.
	2608-5	0.026	0.026	100.
Feb. 6/90	2941-2	0.024	0.025	96.0
	2907-T3	0.040	0.046	87.0
Apr. 11/90	318-33	0.027	0.028	96.4
	319-1	0.054	0.054	100.0

Duplicates

Date	Sample #	Orig. Value	Dupl. Value	Difference	Allow. Diff.	Acceptable
Jan. 24/90	2608-10	0.002	0.002	0.	0.003	yes
	2608-17	0.085	0.087	0.002	0.005	yes
	2608-12	0.001	0.001	0.	0.003	yes
Feb. 6/90	2874-2	0.06	0.06	0.	0.005	yes
	2874-10	0.06	0.06	0.	0.005	yes
	2874-5	0.22	0.24	0.02	0.01	yes
Apr. 11/90	317-4	0.001	<0.001	0.001	0.003	yes

QUALITY CONTROL RESULTS
David Bromley Engineering Ltd.

Sample #2608, 2246, 2874, 317

Parameter: Arsenic

Standard Check Solution (prepared by QA/QC)

Date	Value	Theoretical Value	% Recovery
Jan. 25/90	0.0018	0.0018	100.
Feb. 13/90	0.0009	0.0008	112.5
	0.0010	0.0008	125.0
Apr. 18/90	0.0009	0.0008	112.5

Analyst-Prepared Spikes

Date	Sample	Value	Theoretical Value	% Recovery
Jan. 25/90	2709-215A	0.005	0.005	100.
	2784-1	0.008	0.0077	103.9
Feb. 13/90	2960-1	0.0063	0.0063	100.
	2947-1	0.0065	0.0069	94.2
Apr. 18/90	372-2	0.0066	0.0057	98.2
	386-1	0.0073	0.0072	101.3

Duplicates

Date	Sample #	Orig. Value	Dupl. Value	Difference	Allow. Diff.	Acceptable
Jan. 25/90	2246-2	0.0033	0.0035	0.0002	0.0006	yes
	2608-4	0.0027	0.0029	0.0002	0.0003	yes
	2735-1	0.0050	0.0051	0.0001	0.0006	yes
	2774-2	0.0010	0.0009	0.0001	0.0003	yes
Feb. 13/90	2874-1	0.0011	0.0013	0.0002	0.0003	yes
	2874-13	0.0029	0.0029	0.	0.0003	yes
Apr. 18/90	135-1	0.0006	0.0005	0.0001	0.0003	yes
	317-10	0.0012	0.0014	0.0002	0.0003	yes

QUALITY CONTROL RESULTS
David Bromley Engineering Ltd.

Sample #2608, 2246, 2874, 317

Parameter: Selenium

Standard Check Solution (prepared by QA/QC)

Date	Value	Theoretical Value	% Recovery
Jan. 25/90	0.0017	0.0015	113.
	0.0007	0.0009	77.7
Feb. 13/90	0.0010	0.0009	111.
Apr. 18/90	0.0009	0.0008	112.5

Analyst-Prepared Spikes

Date	Sample	Value	Theoretical Value	% Recovery
Jan. 25/90	2709-215A	0.0053	0.0052	102.
	2784-1	0.0055	0.0056	97.7
Feb. 13/90	2960-1	0.0068	0.0065	105.
	2947	0.0045	0.0050	90.0
Apr. 18/90	372-2	0.0052	0.0053	98.1
	386-1	0.0052	0.0050	104.

Duplicates

Date	Sample #	Orig. Value	Dupl. Value	Difference	Allow. Diff.	Acceptable
Jan. 25/90	2246-2	<0.0002	<0.0002	0.	0.0003	yes
	2608-4	<0.0002	<0.0002	0.	0.0003	yes
	2735-1	0.0018	0.0020	0.0002	0.0003	yes
	2774-2	0.0005	0.0005	0.	0.0003	yes
Feb. 13/90	2874-1	<0.0002	<0.0002	0.	0.0003	yes
	2874-13	<0.0002	<0.0002	0.	0.0003	yes
Apr. 18/90	317-10	<0.0002	<0.0002	0.	0.0003	yes
	376-3	<0.0002	<0.0002	0.	0.0003	yes

X

QUALITY CONTROL RESULTS
David Bromley Engineering Ltd.

Sample #2608, 2246, 2874, 317

Parameter: Mercury (ppb)

Standard Check Solution (prepared by QA/QC)

Date	Value	Theoretical Value	% Recovery
Jan. 24/90	10.9	10.	109.
Feb. 8/90	9.7	10.	97.0
Apr. 18/90	1.10	10.	110.0

Analyst-Prepared Spikes

Date	Sample	Value	Theoretical Value	% Recovery
Jan. 24/90	1841-10	0.46	0.525	87.6
	2807-1	0.60	0.57	105.
Feb. 8/90	2966-1	0.71	0.70	101.
Apr. 18/90	372-2	1.08	1.10	98.2

Duplicates

Date	Sample #	Orig. Value	Dupl. Value	Difference	Allow. Diff.	Acceptable
Jan. 24/90	2841-10	0.05	0.05	0.	0.005	yes
	2662-1	0.05	0.05	0.	0.005	yes
	2868-1	0.05	0.05	0.	0.005	yes
Feb. 8/90	2900-1	0.41	0.44	0.03	0.05	yes
Apr. 18/90	372-2	0.18	0.21	0.03	0.24	yes

QUALITY CONTROL RESULTS
David Bromley Engineering Ltd.

Sample #2608, 2246, 2874, 317

Parameter: Barium by ICP

Standard Check Solution (prepared by QA/QC)

Date	Value	Theoretical Value	% Recovery
Jan. 25/90	0.201	0.207	97.1
Feb. 7/90	0.200	0.207	96.6
Apr. 23/90	0.431	0.460	93.6

Analyst-Prepared Spikes

Date	Sample	Value	Theoretical Value	% Recovery
Jan. 25/90	2608-17	0.753	0.753	100.
Feb. 7/90	2874-12	0.191	0.193	98.9
Apr. 23/90	317-6	0.243	0.256	94.9

Duplicates

Date	Sample #	Orig. Value	Dupl. Value	Difference	Allow. Diff.	Acceptable
Jan. 25/90	2608-17	1.32	1.30	0.02	0.05	yes
	2608-2	232.	238.	6.	10.	yes
Feb. 7/90	2874-12	0.18	0.179	0.001	0.005	yes

QUALITY CONTROL RESULTS
David Bromley Engineering Ltd.

Sample #2608, 2246, 2874, 317

Parameter: Boron by ICP

Standard Check Solution (prepared by QA/QC)

Date	Value	Theoretical Value	% Recovery
Jan. 25/90	0.147	0.153	96.1
Feb. 7/90	0.148	0.153	96.7
Apr. 23/90	0.300	0.34	88.2

Analyst-Prepared Spikes

Date	Sample	Value	Theoretical Value	% Recovery
Jan. 25/90	2608-17	0.327	0.316	103.5
Feb. 7/90	2874-12	0.082	0.082	100.
Apr. 23/90	317-6	0.266	0.225	118.2

Duplicates

Date	Sample #	Orig. Value	Dupl. Value	Difference	Allow. Diff.	Acceptable
Jan. 25/90	2608-17	0.51	0.48	0.03	0.05	yes
Feb. 7/90	2874-12	0.019	0.011	0.008	0.009	yes
	2895-1	0.062	0.054	0.008	0.009	yes

QUALITY CONTROL RESULTS
David Bromley Engineering Ltd.

Sample #2608, 2246, 2874, 317

Parameter: Cadmium by ICP

Standard Check Solution (prepared by QA/QC)

Date	Value	Theoretical Value	% Recovery
Jan. 25/90	0.144	0.144	100.
Feb. 7/90	0.143	0.144	99.3
Apr. 23/90	0.314	0.32	98.1

Analyst-Prepared Spikes

Date	Sample	Value	Theoretical Value	% Recovery
Jan. 25/90	2608-17	0.07	0.072	97.2
Feb. 7/90	2874-12	0.098	0.085	115.
Apr. 23/90	317-6	0.157	0.163	96.3

Duplicates

Date	Sample #	Orig.Value	Dupl.Value	Difference	Allow.Diff.	Acceptable
Jan. 25/90	2608-3	<0.001	<0.001	0.	0.003	yes
	2608-17	<0.001	<0.001	0.	0.003	yes
Feb. 7/90	2874-12	0.024	0.025	0.001	0.003	yes
	2895-1	<0.001	<0.001	0.	0.003	yes

QUALITY CONTROL RESULTS
David Bromley Engineering Ltd.

Sample #2608, 2246, 2874, 317

Parameter: Lead by ICP

Standard Check Solution (prepared by QA/QC)

Date	Value	Theoretical Value	% Recovery
Jan. 25/90	0.166	0.162	102.5
Feb. 7/90	0.169	0.162	104.3
Apr. 23/90	0.350	0.36	97.2

Analyst-Prepared Spikes

Date	Sample	Value	Theoretical Value	% Recovery
Jan. 25/90	2608-17	0.076	0.083	91.6
Feb. 7/90	2874-12	0.099	0.088	112.5
Apr. 23/90	317-6	0.223	0.222	100.5

Duplicates

Date	Sample #	Orig. Value	Dupl. Value	Difference	Allow. Diff.	Acceptable
Jan. 25/90	2608-3	0.01	0.02	0.01	0.02	yes
	2608-17	<0.01	<0.01	0.	0.02	yes
Feb. 7/90	2874-12	<0.010	0.015	0.005	0.02	yes
	2895-1	0.021	0.019	0.002	0.02	yes

QUALITY CONTROL RESULTS
David Bromley Engineering Ltd.

Sample #2608, 2246, 2874, 317

Parameter: Chromium by ICP

Standard Check Solution (prepared by QA/QC)

Date	Value	Theoretical Value	% Recovery
Jan. 25/90	0.167	0.171	97.7
Feb. 7/90	0.163	0.171	95.3
Apr. 23/90	0.351	0.380	92.3

Analyst-Prepared Spikes

Date	Sample	Value	Theoretical Value	% Recovery
Jan. 25/90	2608-17	0.160	0.164	97.7
Feb. 7/90	2874-12	0.080	0.088	90.9
Apr. 23/90	317-6	0.209	0.204	102.5

Duplicates

Date	Sample #	Orig.Value	Dupl.Value	Difference	Allow.Diff.	Acceptable
Jan. 25/90	2608-17	0.164	0.157	0.007	0.01	yes
Feb. 7/90	2874-12	0.003	0.005	0.002	0.002	yes
	2895-1	0.003	0.003	0.	0.002	yes